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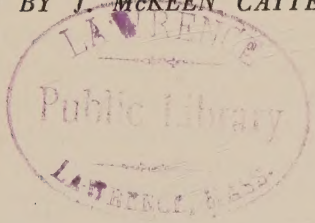

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JULY, 1921

THE HISTORY OF CHEMISTRY*

By Professor JOHN JOHNSTON

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CHEMISTRY is the science of the ultimate composition and constitution of matter, of the mutual reaction between two or more substances, and of the influence of factors such as change of temperature, pressure, or extent of surface upon the stability of a substance and its relation to other substances. The chemist studies the great diversity of substances, organic and inorganic, which we see around us; he analyzes these substances, ascertains their composition, and builds them up again from their components; he investigates their behavior with respect to change in external conditions and in relation to other substances. He learns how, not merely to imitate a substance occuring naturally, but to make the identical material artificially and to discover new substances superior in usefulness to those found in nature; and he considers how useful substances may be produced more economically from the raw materials available. The study of chemistry is slowly yielding information as to the nature of biological processes of importance to every one and so is assisting to retain health and to control disease. Indeed our material well-being and comfort depend in large part upon a fundamental knowledge of chemical processes and how to control them; and continued progress along these lines will be limited only by the rate at which we extend our knowledge of fundamentals, what chemistry has achieved being but a fraction of what it may do for us.

The great practical achievements of chemistry are comparatively recent, almost entirely within the last sixty years, quite largely indeed within the present century. They are so manifold that it would not be feasible in the space allotted even to mention a fraction of them; consequently I have endeavored only to sketch in general outline, as free from technicalities as possible, the development of the main funda-

*A lecture delivered at Yale University, March 25, 1920, the second of a series on the History of Science under the auspices of the Yale Chapter of the Gamma Alpha Graduate Scientific Fraternity.

mental principles of chemistry, and even in this have been forced to omit much that is important.

Development of the Idea of Chemical Elements and of Their Mutual Relationship

Two hundred years ago, at which time the classical mathematics had already reached a high state of development, chemistry had not begun to be a science, nor even an art; it was more or less of a mystery, in which language was used to conceal the fact that there was no thought—as it still is used by some today. Boyle in "The Sceptical Chymist," first published in 1661, refers to the vagueness of the ideas then current in the following terms:[1]

> The confidence wherewith chymists are wont to call each of the substances we speak of by the name of sulphur or mercury, or the other of the hypostatical principles, and the intolerable ambiguity they allow themselves in their writings and expressions, makes it necessary for me . . . . to complain of the unreasonable liberty they give themselves of playing with names at pleasure . . . . I cannot but take notice, that the descriptions they give us of that principle or ingredient of mixt bodies, are so intricate, that even those that have endeavored to polish and illustrate the notions of the chymists, are fain to confess that they know not what to make of it either by ingenuous acknowledgments, or descriptions that are not intelligible . . . . Chymists write thus darkly, not because they think their notions too precious to be explained, but because they fear that if they were explained, men would discern, that they are far from being precious. And, indeed, I fear that the chief reason why chymists have written so obscurely of their three principles, may be, that not having clear and distinct notions of them themselves, they cannot write otherwise than confusedly of what they but confusedly apprehend; not to say that divers of them, being conscious to the invalidity of their doctrine, might well enough discerne that they could scarce keep themselves from being confuted, but by keeping themselves from being clearly understood . . . . If judicious men, skilled in chymical affairs, shall agree to write clearly and plainly of them, and thereby keep men from being stunned, as it were, or imposed upon by dark and empty words; it is to be hoped, that these (other) men finding, that they can no longer write impertinently and absurdly, without being laughed at for doing so, will be reduced either to write nothing, or books, that may teach us something, and not rob men, as formerly, of invaluable time; and so ceasing to trouble the world with riddles or impertinencies, we shall either by their books receive an advantage, or by their silence escape an inconvenience.

And again,[2] showing that he had no great opinion of their methods:

> Methinks the Chymists, in their searches after truth, are not unlike the navigators of Solomon's Tarshish fleet, who brought home from their long and tedious voyages, not only gold, and silver, and ivory, but apes and peacocks too: for so the writings of several (for I say not, all) of your hermetick philosophers present us, together with divers substantial and noble experiments, theories, which either like peacock's feathers make a great

[1] The Sceptical Chymist, Everyman's Edition, pp. 113-6.
[2] Op. cit. p. 227.

show, but are neither solid nor useful; or else like apes, if they have some appearance of being rational, are blemished with some absurdity or other, that when they are attentively considered, make them appear ridiculous.

The general belief of the alchemists appears to have been that there is a primordial matter which, when combined with more or less of one or more of their four so-called elements or principles—fire, air, earth and water—becomes apparent to our senses as the various substances we know; in other words, that matter is the carrier or embodiment of certain qualities which can by appropriate treatment be enhanced or attenuated. It is juster to look upon the alchemists' so-called elements as qualities—such as hotness, coldness, dryness, wetness—typified by the things named, though no single quality would suffice for a single element, as each alchemist tended to endow his elements with such attributes as suited his immediate purpose. In addition to these four elements some made use also of the "hypostatical" (fundamental) principles—salt, sulphur and mercury, which again may be interpreted as typifying fixity in the fire or incombustibility, combustibility, volatility and metallic lustre, respectively. Such views lead one directly to believe in the possibility of transmutation, of changing base metal into gold; for to achieve this, it would be necessary only to effect a suitable change in the proportions of the elemental qualities, a possibility which therefore seemed far from hopeless or absurd.

It is clear that no great progress in chemistry as a science could have been made, so long as such false views prevailed. And indeed the alchemists contributed nothing to the real philosophy of chemistry, although they did discover—by chance, more or less—a few useful substances, such as sulphuric acid (oil of vitrol) and tartar emetic, some of which found application as drugs. For one of the tasks they set for themselves was to find the elixir of youth, a quest along with which went a belief in the efficacy of doses of the strangest mixtures; indeed, an ingenuous person examining the present-day official pharmacopeias might well be led to think that the alchemists continued to flourish and to be powerful until very recent times.

The overthrow of this false philosophy was begun by Robert Boyle, in his "Sceptical Chymist." He endeavored to distinguish the qualities of a substance from its composition, and enunciated views with reference to the difference between elements and compounds which are still held. Thus he writes: "I must not look upon any body as a true principle or element, but as yet compounded, which is not perfectly homogeneous, but is further resoluble into any number of distinct substances, how small soever." "I mean by elements, as those chymists that speak plainest do by their principles, certain primitive and simple, or perfectly unmingled bodies; which not being made of any other bodies, or of one another, are the ingredients of which all those called

perfectly mixt bodies are immediately compounded, and into which they are ultimately resolved."[3]

It is difficult to picture the exact status of knowledge of chemical art at that period, partly because the alchemists commonly described their experiments in vague terms, partly because their false theories prevented them from discovering all the pertinent facts and led them to misinterpret much of what they did observe. For instance, the doctrine of the indestructibility of matter—that the total weight of a system remains unaffected by chemical changes taking place within it—now regarded as axiomatic, was not definitely formulated; the material nature of air had not yet been recognized, nor had gases been really differentiated; the process of combustion was not understood, and analytical methods hardly existed.

Boyle's views gained ground very slowly, but the progress of chemistry was hindered for a century by a false theory, the so-called phlogiston theory. According to this view, there is an inflammable principle—phlogiston—which escapes when a substance is burned. For instance, when a metal is burned, phlogiston escapes and a calx or earth remains; on which basis the metal is a compound of calx plus phlogiston, whence it would follow that in order to regenerate the metal, phlogiston must be supplied to the calx by heating with some substance (such as carbon) rich in phlogiston. This theory emphasized the fundamental similarity of all combustion processes, and to that extent was a good and useful hypothesis; but the picture it presented is almost the exact inverse of the real facts, for we now know that a metal in burning actually unites with oxygen, that the calx or oxide weighs more than the metal, and that the system as a whole has lost energy, mainly in the form of heat—all of these changes having to be reversed in order to regenerate the metal from the oxide. The phlogiston theory, despite its falsity, continued to prevail for a century, during which time it befogged the whole subject and paralyzed the advance of chemical philosophy; the net result being that, until nearly the end of the eighteenth century, the subject was as little clear as it had been a hundred years before, although it had in the meantime been enriched by many new observations of importance, and progress along experimental lines had been quickened by improved technique. This prevalence of a false theory, which hindred progress so greatly, leads one to wonder if some of the hypotheses now commonly accepted do not have a similar inverse relation to the real facts, as was the case with the phlogiston theory; it is this type of question which the promoters of the theory of relativity are in effect asking with respect to our fundamental physical ideas.

Another mistaken notion was the material nature of heat. The fact

[3]Op. cit. p. 187.

that flames issue from burning bodies led to the view that they were material objects; and so fire was regarded as one of the elements. Even after the overthrow of the ancient ideas of combustion, it was believed that heat, or caloric as they termed it, though devoid of weight, was a substance—an imponderable, in the same category as light and electricity.

Thus, even as late as 1848, in a very interesting "Manual of Chemistry"[4] the author writes:

> The first part comprehends an account of the nature and properties of Heat, Light and Electricity—agents so diffusive and subtile that the common attributes of matter can not be perceived in them. They are altogether destitute of weight; at least, if they possess any, it cannot be discovered by our most delicate balances, and hence they have received the appellation of Imponderables. They cannot be confined and exhibited in a mass like other bodies, they can be collected only through the intervention of other substances. Their title to be considered material is therefore questionable, and the effects produced by them have accordingly been attributed to certain motions or affections of common matter. It must be admitted, however, that they appear to be subject to the same powers that act on matter in general, and that some of the laws which have been determined concerning them are exactly such as might have been anticipated on the supposition of their materiality. It hence follows that we need only regard them as subtile species of matter, in order that the phenomena to which they give rise may be explained in the language, and according to the principles, which are applied to material substances in general.

From this it is apparent that the author did not feel quite sure of his ground although Rumford's experiments in 1798 had shown that heat could be generated without limit by friction alone; indeed the question was not determined until the experimental investigations of Joule, published 1843-9, established the doctrine of the conservation of energy, that heat and work are mutually and quantitatively interconvertible.

Thus, up to nearly the close of the 18th century chemistry had not become a science. No descriptions had yet been given which correlated change of properties with change of composition in such a way as to indicate new lines of investigation. Indeed the conception of chemical composition, as we now understand it, had not taken form, because the phenomena—and in particular, the change of weight—accompanying the transformation of one substance into another had not been accurately observed. From this period date the use of the balance, perhaps the most characteristic single tool of the scientific chemist, and the quantitative analysis of chemical changes; and with this advance chemistry begins to be a science, with a growing body of definite principles.

[4] "Manual of Chemistry on the Basis of Dr. Turner's Elements of Chemistry," by John Johnston (1806-79) Professor of Natural Science in the Wesleyan University; new edition, Philadelphia, 1848; p. xiii.

In rendering chemistry a science many men bore a part, but the outstanding figure is Lavoisier, born in 1743, beheaded in 1794 because "the Republic has no need of scientists," a view which, though still widely held implicitly, is not now carried to its logical conclusion in the same way as it was then. Lavoisier's "Traité élémentaire de chimie," published in 1789, is a systematic treatise which transformed the subject. He gave a definite meaning to the expression, "chemical composition"; and recognized that the quantity of matter is the same at the end as at the beginning of every operation. He stated that the object of chemistry is "to decompose the different natural bodies, and . . . . . to examine separately the different substances which enter into their combination. We cannot be certain that what we think today to be simple is indeed simple; all we may say is, that such or such a substance is the actual term whereat chemical analysis has arrived, and that with our present knowledge we are unable to subdivide further." This quotation shows that Lavoisier had a much better philosophic attitude towards the whole matter than have had many of the chemists since his time; indeed until recently chemists were so much occupied in accumulating observations that they were prone to neglect the philosophy by means of which alone these multitudinous observations can be correlated.

Lavoisier gave a table of elements, containing thirty-three names, of which twenty-three are still regarded as elements—the definition of a chemical element being that it is a substance which we have not succeeded in breaking up into anything simpler, the atoms of the several chemical elements therefore being, so to speak, the small pieces of tile of different kinds out of which are built up all of the numberless patterns or mosaics which we see about us as diverse kinds of matter. Of the others, five—lime, magnesia, baryta, alumina, silica—are oxides which, with the experimental means then available to Lavoisier, could not be decomposed. These twenty-three elements, the number known at the end of the eighteenth century, comprise the following: carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur; antimony, arsenic, bismuth, cobalt, copper, gold, iron, lead, manganese, mercury, molybdenum, nickel, platinum, silver, tin, tungsten, zinc. This list, it will be noted, includes only six non-metals, one of which—sulphur—was known to the ancients though not recognized by them as an element in the modern sense of the term. Of the seventeen metals on Lavoisier's list, seven—gold, silver, copper, iron, mercury, lead, tin—were known to the ancients, though not as elements; most of the others were isolated for the first time during the second half of the eighteenth century. Incidentally it may be mentioned, as an illustration of the slowness with which knowledge is applied, that some of these metals—notably, tungsten, molybdenum and manganese—were not used technically for

more than a hundred years after their discovery; we now value them highly, as their use enables us to achieve results of the greatest importance technically and therefore economically, results which otherwise were unattainable. It is of interest, furthermore, to note that the names of two of these elements—cobalt and nickel—derive from words meaning "the devil," ores of copper admixed with these metals being then considered useless; indeed we have only learned to make use of such ores comparatively recently. Nickel has been produced on a large scale for a short time, and no large use has yet been made of cobalt, although it is comparatively plentiful.

By the year 1800, twenty-seven chemical elements had been recognized, the four added since Lavoisier being uranium, titanium, chromium and tellurium; thirty years later, in 1830, this number had been doubled. The discovery of many of these elements (for instance, the metals associated with platinum—palladium, rhodium, iridium, osmium) was brought about by the application of more and more careful analytical methods, in the hands of men such as Wollaston and Berzelius—the latter alone adding five to the list. The isolation of others, notably the alkali and alkaline earth metals, (potassium, sodium, calcium, strontium, barium) by Davy in 1807, was achieved by a new and powerful method of analysis, namely, the application of the electric current to the breaking up of substances. Davy, after proving definitely by this means that water is composed solely of hydrogen and oxygen, established the fact, surmised by Lavoisier, that the alkalis are oxides of metals; therefore that oxygen, the acid producer as it had been named (erroneously as we now know), is a constituent of the alkalies. He was, however, puzzled by ammonia and in particular by the ammonium radicle or grouping[6] which in its salts resembles so closely the alkali metals; and this puzzle was not solved until about 1840, by which time the idea of the existence of similar compound radicles in organic chemistry was beginning to find general acceptance.

From this period dates the usefulness of the atomic theory, first clearly enunciated by John Dalton in his "New System of Chemical Philosophy" published in 1808. The speculation that matter is ultimately composed of discrete particles, or atoms, had been common in philosophical writings; but it had led to no real progress of knowledge until Dalton showed how the assumption that each element is made up of atoms serves to correlate experimental observations and to suggest new inquiries. On this basis, the myriad substances we see about us are all made up of combinations of a small integral number of atoms of the several elements present, the atoms of each element having characteristic properties, and in particular a characteristic weight. Chemical combination of one element with another is the union of an

[6]See *infra.*

atom of one element with an atom, or a small number of atoms, of the other; this number, in compounds of two elements, seldom exceeds four and is always less than eight, and it is in no wise arbitrary but in accordance with what is now termed the relative valence of the two elements. As a simple case, in the ordinary combustion of carbon (coal) one carbon atom unites with two oxygen atoms, resulting in the formation of carbonic acid gas; or, as the chemist writes it in his shorthand, $C + O_2 = CO_2$. In more complicated structures, the number of elements present may be greater than two, but is seldom greater than five; the total number of atoms making up the structure characteristic of the substance is in some cases large, but in all cases it can be pictured as made up of a number of groupings, each composed of two elements. As a simple familiar instance, limestone ($CaCO_3$) is made up of equivalent amounts of lime (CaO) and carbonic acid (CO_2), and is decomposed into these two proximate constituents in the operation of lime-burning, thus:

$$\underset{\text{calcium carbonate}}{CaCO_3\ (CaO.CO_2)} = \underset{\text{calcium oxide}}{CaO} + \underset{\text{carbon dioxide}}{CO_2}\ .$$

Furthermore the lime, when used as mortar, is slowly reconverted into the carbonate by the action of the carbonic acid always present in the atmosphere. In many chemical processes we are dealing with an exchange of partners, the substances A B and C D becoming A D and B C; for example, hydrochloric (muriatic) acid added to a solution of silver nitrate (lunar caustic) yields nitric acid and silver chloride, the latter appearing as an insoluble white curdy substance; or in symbols, $HCl + AgNO_3 = HNO_3 + AgCl$. This illustrates the fact that the apparent affinity of one kind of atom for another is not the same under all circumstances, and that consequently a firm and long-standing union of two atoms may be broken up by the entrance of a third under appropriate conditions.

The atomic theory was a very great step in advance, establishing, as it did, the laws and processes of chemistry on a quantitative basis. Progress since Dalton's time has only served to confirm the essential correctness of the atomic theory; indeed there is now no longer need to call it a theory, for the reality of atoms is no more open to question than that of any other fact of physical science. The atoms are infinitesimally small, so small that, if a drop of water were magnified to the size of the earth, the constituent atoms would be about the size of footballs. Perhaps a more striking illustration is that, if the particles in a cubic inch of air were magnified until they would just pass through a very fine sieve (100 meshes to the inch), this fine sand of particles would suffice to cover a highway extending from New York to San Francisco, and one mile wide, with a layer about two feet deep.

We cannot see the actual atoms, it is true, but we can weigh them and measure them and study their characteristics; the same holds true for electricity, which, it may be remarked, is, according to modern views, also made up of units, named electrons, which bear an extraordinarily intimate relation to the structure of the atom itself.

In 1830, as noted above, about fifty-five chemical elements had been recognized, and these include all—with one notable exception, argon, to which we shall refer later—which have yet been found in appreciable quantities in the surface crust of the earth. Since that time the number of recognized elements has been increased by about thirty, most of which, however, are so very rare that only a few grams of them have ever been isolated—in other words, most of them are chemical curiosities kept in small tubes in museums. Indeed the recognition and isolation of the majority of these elements has been possible only through the discovery, about 1860, of the possibility of spectrum analysis. This elegant method depends upon the fact that each chemical element, whether in combination or free, gives, when viewed under appropriate conditions, a so-called spectrum made up of a series of bright lines, the positions, or colors, of which are absolutely characteristic. This method of identification is so sensitive that an element can be recognized even when it is present only in very small amount—an amount of the order of one-millionth of a gram; it therefore enables one to learn how to segregate or concentrate an element originally present in such small quantities that no ordinary chemical test would then suffice to detect it. Likewise, by observation and measurement of the spectra of the sun and stars, it has been definitely determined that the elements present in their upper layers are identical with those which make up the crust of the earth and are already familiar to us, with one or two possible exceptions.

In 1868 Lockyer, while examining the solar spectrum, observed a bright line which did not correspond to any element then known, and attributed it to a hypothetical element helium. This element was not recognized on the earth for about thirty years, although Hillebrand had in the meantime, while examining the mineral uraninite, had some in his hands, but, by reason of its inertness, considered it to be merely nitrogen. It was identified by Rayleigh and Ramsay in the course of their investigation of the inert gases of the atmosphere, an investigation which arose out of the observation—originally made, in a sense, by Cavendish, a century earlier—that there is a fractional difference in density between nitrogen prepared chemically and that obtained from purified air by removal of the oxygen. This investigation resulted in the discovery of a family of five new inert gaseous elements, all of which are present in the atmosphere, argon to the extent of about one percent. by volume, helium and the others in the proportion of a few

parts per million. Argon, therefore, although all around us in enormous quantities—within a house 33 x 33 x 33 feet there is about a ton of air and consequently some forty pounds or 10,000 litres (400 cubic feet) of argon—was not recognized, by reason of its inertness; for neither it, nor any of the argon group, has hitherto been made to enter into chemical combination. But this very inertness is now being taken advantage of; in the case of argon, as a filling for electric light bulbs; in the case of helium, as a non-inflammable filling for balloons, a matter which, during the war, was considered so important that large quantities of it were finally separated from natural gas in Texas, after many difficulties and at very large expense. Incidentally, this is an excellent illustration of the results which may follow from scientific work carried on merely to learn about things, and not with any idea of discovering something of particular use; for the possibility of producing helium on a large scale is a direct outcome of careful observations of the spectrum of various samples of natural gas.

But the greatest interest in helium, from a scientific point of view at least, is in quite another direction, namely, its intimate connection with the phenomenon of radio-activity, or better, with the disintegration of the so-called radio-elements. These radio-elements, the best known of which is radium, first discovered in 1898, differ from the other chemical elements in one respect, but that one very significant, in that they are disintegrating before our eyes. This disintegration, which proceeds at a rate unaffected by any change of temperature or by anything tried hitherto, is accompanied by a continuous emission of energy—a million times greater than is liberated in any change of matter previously known—largely in the form of material particles shot out with great velocity. This energy is so great that one can indeed count the number of particles shot out by observing the flash produced by the bombardment of a suitable screen, as in the spinthariscope, or the luminous watch dial in which the light is the aggregate of the flashes produced by a quantity of radium which weighs only a millionth of a gram. This phenomenon enables us to detect the presence of a small number of *atoms* of a radio-element; whereas the smallest number of atoms of an element which it has been possible to detect by means of the spectroscope or by the most delicate methods of chemical analysis is at least 10^{12}, a number the magnitude of which will be more obvious from the statement that it is several hundred times the total present human population of the world. It is now definitely established that these material particles are helium atoms, and that this disintegration of the radio-elements is an actual transmutation, a transmutation, however, beyond our present powers to control. If we should ever learn to control this atomic disintegration, it would effect a much greater revolution than was caused by the utilization of coal for power; for in that

case the energy derivable from the atomic disintegration of a shovelful of material would be as great as that now derivable from a thousand tons of coal—in other words we would then be possessed of limitless stores of energy. This has not been done yet, it may not be achieved for a long time, it may not be possible; but he would be a rash man who would deny its possibility. The phenomenon of radio-activity is a very striking illustration of the way in which a new method, a new tool of research, may open up a field which otherwise we would not even sense—nay, hardly be bold enough to imagine; and there is absolutely no reason for believing that other equally novel and unsuspected discoveries will not be made in the future.

From the fact that the material particles shot out by a disintegrating radio-element are helium atoms, it would appear that the helium atom is one of the kinds of brick which go to make up the more complex type of structure of the atoms of the heavier elements. Now the two simplest and lightest atoms known are the hydrogen atom and the helium atom; and there is ground for believing that the hydrogen atom also is one of the bricks of the atom-builder. Indeed recent experiments of Rutherford (1920) indicate that he has succeeded, by bombarding nitrogen atoms with helium atoms, in dislodging hydrogen atoms from somewhere—presumably from the nitrogen atom. If this is confirmed, we shall have to introduce an interpretative reservation into the present definition of an element, according to which a chemical element is a substance not yet resolved into something simpler. This however, is hardly part of the *history* of chemistry; though, one may ask, what is the use of history, beyond being a sort of literary exercise, if it does not enable us to make general predictions as to what is going to happen, for then only will it be a science.

The deduction from experimental evidence that the hydrogen and the helium atom are two of the building bricks brings us back to a very old idea, to the idea that matter as we see it or—one would now say preferably,—the chemical elements are made up of one, two, or at most a few, kinds of primordial stuff. The relative weight of the atoms of the several elements can be determined by simple experiments; these atomic weights were usually referred to hydrogen as unity, hydrogen being the lightest known element, but for practical reasons are now referred to oxygen = 16.00, there being only a fractional difference between these two standards of reference. It was early observed that a much larger proportion of these atomic weights approximate to whole numbers than can be accounted for on the theory of chances. From this it was inferred that the hydrogen atom was this ultimate unit; but there were a number of well established marked exceptions[7] which would not be explained away and so tended to discredit the doctrine. Nevertheless this hypothesis, often called Prout's hypothesis, continued

to be a useful one, as it was the occasion of much of the best work on atomic weights; and in spite of the exceptions, it persisted as an aspiration which was rewarded in time by the discovery of the periodic law of the chemical elements, established by the writings of Mendelejeff.

According to this great generalization "The properties of the elements, and, therefore, the properties of the simple, and of the compound bodies formed from them, are in periodic dependence on their atomic weights." In other words, if the elements are arranged in order of increasing atomic weight, we find that like properties recur regularly, and that by this means like elements are brought together into natural groups, e. g. the alkali metals, the halogens, the inert gases. This periodic classification had a profound effect in leading us toward the correct value of atomic weight of many elements; and in enabling predictions to be made as to the existence and properties of undiscovered elements, predictions which were completely verified in three cases by the subsequent discovery and investigation of the properties and relations of scandium, gallium and germanium. But to record all the consequences of this periodic law would be to recount the achievements in inorganic chemistry in the fifty years elapsed since its discovery; suffice it to say that it forced the chemist to cease thinking about the elements as unrelated entities and instead, to consider them as members of a family or, at the least, as members of a series of related families.

Time has only served to corroborate the essential correctness and usefulness of the periodic classification of the chemical elements; and no evidence has been more conclusive than that derived, within the last few years, from investigations of X-rays and of radio-activity. This work has led to the conception of a characteristic atomic number which changes by unity in passing from one element to its neighbor in the periodic system. It appears indeed that this atomic number is really more fundamental than the atomic weight, that all the properties of an atom, save mass and radio-activity, depend upon the atomic number, which is the number of negative electrons (i. e. atoms of electricity) surrounding the positive nucleus at which the mass of the atom is assumed to be concentrated; or rather, that the distribution of the negative electrons on which the ordinary physical and chemical properties depend is a function, and a periodic function, of the units of electric charge on the nucleus, and hence of the atomic number. It is believed that the lightest known element hydrogen has an atomic number of 1, helium of 2, lithium of 3, and so on up to thorium and uranium, the

[7]These are now showing signs of yielding, in that the elements in question seem to be mixtures of so-called isotopes which have identical chemical properties, and so can not be separated by chemical means, but differ slightly in characteristic weight.

heaviest known elements, with atomic numbers of 91 and 92 respectively. If these views should be confirmed—and their success in correlating diverse phenomena makes it certain that the picture they present is one aspect of reality—we shall have nearly returned to the hypothesis of a primordial stuff; for present evidence indicates that the positive nuclei of hydrogen and helium and the negative electron are amongst the units from which the atoms of the elements are built. But this again is history in the making.

From the considerations just outlined it appears that all of the chemical elements as we know them are of a similar order of complexity, since they belong to a series of families; and consequently that any means which will decompose one element will also decompose others. Moreover, the sequence of atomic numbers indicates that only five elements are missing in the series up to uranium, the heaviest element now known and the parent of one of the two series of radio-active elements. Whether elements heavier than uranium exist is open to question; if they do exist, they would presumably be radio-active, and with a shorter life than uranium. The most common elements in and about the surface layers of the earth are in general elements of smaller atomic number, as is shown by an estimate of the percentage of the several elements which go to make up the earth's "crust," defined for this purpose as a layer ten miles in thickness.

It appears that two elements, oxygen and silicon—the latter wholly in primary combination with the former, the remainder of the oxygen being combined with the other elements—together constitute three-quarters of the earth's crust; and that the eight most abundant elements make up nearly 99 per cent. of the whole.

It is also noteworthy that, of the metals in daily and common use, only aluminum, iron, manganese, chromium, vanadium, and nickel, appear among those elements that are present in the rocks of the crust in sufficient amount to be commonly determinable by the usual processes of analysis. Such common and "every-day" metals as copper, zinc, lead, tin, mercury, silver, gold, and platinum, antimony, arsenic, and bismuth—metals that are of the utmost importance to our civilization and our daily needs—all these are to be found in igneous rocks, if at all, only in scarcely detectable amounts. Though they are ultimately derived from the igneous rocks, they are made available for our use only by processes of concentration into so-called ore bodies.[8]

Up to the present, then, the number of known chemical elements is, excluding the isotopic radio-elements, about eighty. That is, chemists, in spite of laborious and prolonged efforts, analyzing all manner of material from all quarters of the globe—and even from the heavens in the form of meteorites—have been able to resolve their multitudinous diversity into combinations and permutations of some eighty substances; and these hitherto irreducible minima—the so-called chemical

[8]H. S. Washington, J. Franklin Institute, Dec., 1920, p. 778.

elements—are members of a family, or of a group of families, and so represent the same stage of simplicity or complexity of structure. Knowledge of the structure of the atom is extending rapidly, but it would lead too far afield to go into this absorbing question here.

Development of Ideas Respecting Chemical Combination, Particularly in Organic Chemistry

The chemical elements are not all of the same degree of importance to us, although there are not very many which we could well do without; but there are four, in a sense, of supreme importance, as they are the main constituents of all living matter. These four elements are carbon, hydrogen, oxygen, nitrogen, with which are associated relatively small, but absolutely indispensable, proportions of other elements. For a long time it was thought that the substances which make up living matter—the so-called organic compounds—were associated with some sort of vital force, and so were to be placed in another category from mineral substances—the inorganic compounds. But this distinction was broken down, for the first time, nearly one hundred years ago; it remains now only in the names organic and inorganic chemistry, the term organic chemistry now connoting merely the chemistry of carbon compounds, from whatever source derived.

So long as the idea persisted that the behavior of organic substances is determined more or less by a mysterious vital force, progress, it is obvious, could hardly be rapid; and indeed the rise of organic chemistry as a science may be said to date from Wöhler's discovery, in 1828, that urea—a typical product of the animal organism—could be made from materials classed as inorganic compounds. Under certain conditions, the molecule[9] of ammonium cyanate, which is a compound of the ammonium radicle (NH_4) with the cyanate radicle (CNO), undergoes a rearrangement, a change of grouping, yielding urea; or as we would now symbolise it

$$\underset{\text{ammonium cyanate}}{NH_4 \cdot OCN} \longrightarrow \underset{\text{urea}}{OC < \begin{matrix} NH_2 \\ NH_2 \end{matrix}}$$

Here we have, therefore, two different substances composed of the same atoms, and convertible one into another by appropriate treatment; this instance illustrates the fact that the properties of a compound de-

[9]The molecule may be defined, for our present purpose, as the smallest portion of a compound which can be conceived to exist alone; for subdivision if it were carried further, would break up the compound into its constituent parts. The radicle is a grouping of elements, which reacts as a unit and is like a chemical element in many respects, with the outstanding difference that the radicle can, by appropriate treatment, be decomposed into its elements or altered.

pend, not only upon the kinds of atoms and number of each present, but also upon the *arrangement* of these atoms within the molecule. In other words, the behavior of a substance is dependent upon its constitution, just as the behavior of an animal is dependent upon its constitution. But this is to anticipate by some thirty years; for at that time chemists were still a long way from a clear understanding of the matter. The primary reason was a confusion between the atomic weight and the combining weight to be assigned to an element; this confusion resulted in a lack of consistency in assigning formulae to substances—for instance water was then frequently written HO—a circumstance which in turn, so to speak, hid the simple relations of the several compounds and, indeed, makes it hard for us now to follow much of the writing on chemistry at that time. But it would lead too far into a field of interest only to the chemist, to recount the various steps in the slow advance towards an attainment of consistent ideas of chemical combination and constitution. We can only mention some of the outstanding figures in this advance: Wöhler and Liebig, with their discovery (1832) of the radicle benzoyl; Dumas, with his older type theory (1839), Gerhardt and Williamson with modified theories of types of formulation of organic compounds.

Liebig's name cannot however be passed over without mention of the enormous influence which he and his teaching had upon the development of the subject. Shortly after becoming professor at Giessen in 1824 he instituted systematic laboratory instruction in chemistry, and Giessen soon became the most famous chemical school in the world, attracting many who were subsequently themselves to become leaders in further development. Still more important was Liebig's pioneer work on the chemistry of the processes of life, both animal and vegetable, work which makes him the real founder of two branches of the subject—biochemistry and the chemistry of agriculture; the development of these two branches is being attended with incalculable benefits to human welfare.

From about 1830 onwards, interest in chemistry enhanced steadily, the number of competent workers grew rapidly, and there was a constantly increasing body of facts of observation; but these various observations and the deductions from them awaited reconciliation and interpretation which came only when the proper theory was developed. This did not happen until 1860 when, at a conference which had been called in the hope of bringing about some more general understanding of the questions at issue, Carrizzaro brought to the attention of the chemical world the hypothesis of Avogadro, showed how on this basis the apparent anomalies disappear, and so clarified the whole situation. Indeed it may be said that modern chemistry dates from 1860, with the enunciation of clear and consistent views with respect to chemical com-

bination, as a direct consequence of grasping the real significance of Avogadro's hypothesis.

From the gas-laws of Boyle and Gay-Lussac—namely, that equal changes in pressure and in temperature occasion equal changes in equal volumes of gases—and from Gay-Lussac's discovery (1809), that two gases reacting with one another do so in simple proportions by volume and that the volume of the product, when gaseous, also bears a simple relation to that of the factors,—reasoning from these Avogadro about 1811 was led to the hypothesis: Under the same conditions of temperature and pressure, equal volumes of gases contain equal numbers of molecules. The molecule is the smallest particle of a substance obtainable by *mechanical* subdivision; the atom can be obtained only by *chemical* subdivision of the molecule of which it constitutes a part, and is therefore a particle usually incapable of persisting alone but in most cases existing only in combination with other atoms. This combination may be between like atoms, in which case the molecule so formed is that of the element itself, or between unlike atoms, constituting the molecule of a compound. In either case the same principle holds; with the obvious deduction, as Avogadro showed, that the relative weight of two species of gaseous molecules is measured by the ratio of the weights of equal volumes, under the same conditions of temperature and pressure,—i. e. of the densities—of the two gases. A molecule of the elements which are gaseous under ordinary conditions is made up of two atoms, with exception of the family of rare inert gases which are monoatomic; that of other elements,—for example, sulphur—may contain six or more; in all cases there is, as we now know, a progressive dissociation of the molecules with increasing temperature and diminishing pressure, so that at the highest temperatures and lowest pressures a large proportion of the molecules are in effect broken up into monoatomic particles.

With the acceptance of Avogadro's hypothesis, the chemist had at last a definite criterion for deciding when he was dealing with really comparable quantities of elements or of compounds; he was enabled to fix the atomic weight definitely, and hence to deduce the correct empirical formula of his compounds. When this was done, many things became clear. For instance, the full significance of the idea underlying the theories of radicles and types, which had been developing for the previous twenty or thirty years, became apparent; and this, in turn, led to the conception of valence, according to which the atom of each element has a maximum saturation capacity with respect to other atoms.

Certain groupings of atoms are so relatively stable that they remain in combination although chemical change is effected in the molecule as a whole; such groupings, known as radicles, react commonly as units and are therefore in many respects analogous to chemical elements, the

chief differences being that the radicle cannot commonly be isolated as such and that it can, of course, be decomposed into its constituent elements. The earliest clear example is the ammonium radicle (NH_4) which forms a whole series of salts differing no more from the corresponding salts of potassium (K) and sodium (Na) than these differ from one another; in other words, NH_4 can, in principle, replace K or Na in a whole series of compounds each of which closely resembles its analogue. Likewise we have a whole series of organic radicles, ranging from the simplest—methyl (CH_3), ethyl (C_2H_5 or $CH_3.CH_2$)—up to quite complex groupings,—such as stearyl ($C_{17}H_{35}CO$ or $CH_3.(CH_2)_{16}CO$) but all ideally reducible to a small number of types. For instance, consider the following series of compounds, with the corresponding analogues in which hydrogen (H) is substituted for methyl (CH_3):

$CH_3 \cdot H$ methane, the main constituent of natural gas	$H \cdot H$ hydrogen gas
$CH_3 \cdot OH$ methyl alcohol	$H \cdot OH$ water
$CH_3 \cdot Cl$ methyl chloride	$H \cdot Cl$ hydrochloric acid
$CH_3 \cdot CHO$ acetaldehyde	$H \cdot CHO$ formaldehyde (formalin)
$CH_3 \cdot COOH$ acetic acid (vinegar)	$H \cdot COOH$ formic acid
$(CH_3)_2O$ methyl ether	H_2O water
$(CH_3)_2S$ methyl sulphide	H_2S hydrogen sulphide

This list could be extended indefinitely, in either direction; for a whole series of other radicles can be regarded as derived from methyl by successive substitution in place of one or more of its H atoms, of CH_3 groups or chlorine atoms or indeed of any other atom or radicle which exhibits the appropriate affinity relations. For instance, we have:

$CH_2 \cdot H$	$CH_2 \cdot CH_3$	$CH_2 \cdot CH_2 \cdot CH_3$	$CH_2 \cdot CH_2 \cdot CH_2 \cdot CH_3$
CH_3	C_2H_5	C_3H_7	C_4H_9
methyl	ethyl	propyl	butyl

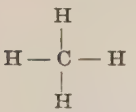
and so on, in homologous series, as it is termed; further C_2H_4Cl, chlorethyl as in $(C_2H_4Cl)_2S$, dichlorethylsulphide (mustard gas); CCl_3, trichloromethyl, as in $CCl_3 \cdot CHO$, trichloraldehyde (chloral), and so on.

With the recognition of the relationships just outlined, of the existence of radicles related to one another in a simple manner and of the fact that the multifarious compounds are formed by the possible combinations of the several radicles and elements, it became possible to organize a consistent nomenclature. The advantage of this is obvious; for if to each chemical compound had been assigned an arbitrary name (as has been the case in naming minerals) it would have been possible to read chemical literature only by memorizing a list numbered now in hundreds of thousands—a task which would have been harder than learning the Chinese characters, and would have resulted in a similar retardation of progress. For certain common substances or common

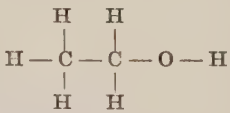
groupings specific names are retained, but in general the name is designed to exhibit the constitution—and therefore the general properties and behavior—of the substance with the least possible memory work; and the chemist gets from these names, in some cases apparently very complicated—e. g. phenyl-dimethyl-isopyrazolone (antipyrin), dimethyl-methane-diethyl-sulphone (sulphonal)—much more information about the substance than the layman gathers from the term "third assistant secretary to the fourth assistant postmaster-general" with respect to the real function of that personage. As simple examples of systematic naming, consider the substances obtainable by chlorinating methane:

CH_4	CH_3Cl	CH_2Cl_2	$CHCl_3$	CCl_4
methane	chloromethane (methyl chloride)	dichloromethane	trichloromethane (chloroform)	tetrachloromethane (carbon tetrachloride)

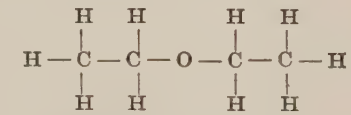
Closely allied to the doctrine of radicles and types is the doctrine of valency, according to which each element has a maximum saturation capacity with respect to other elements. This doctrine developed about the same time, though in somewhat more rigid form than would now be generally accepted. Accordingly, to carbon was assigned the valence 4, to oxygen 2, to hydrogen and chlorine 1, and so on; and it was but a short transition to picture the valence numbers as the number of linkings or bonds with which one atom may hold others, and from this to the writing of graphic or structural formulæ. The graphic formula enabled the organic chemist to represent still more satisfactorily the structure of his substances, and has been an indispensable tool in the subsequent great development of organic chemistry; the following simple examples will suffice:



methane



ethyl alcohol



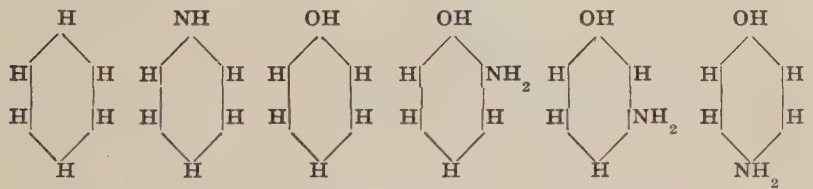
(diethyl) ether

In 1861 appeared the first portion of Kékulé's great text-book which emphasized and illustrated the new views with hundreds of examples. The foundations of modern organic chemistry were therein laid and, what is more important for us here, the date marks the time when the great contribution of organic chemistry to the historical development of the science as a whole was fully rendered.[10]

So far we have mentioned only compounds whose structure can be represented by a straight chain of carbon atoms, and grouped under the general name of aliphatic (or fatty) compounds from the circumstance that fats belong to this category. But there is another category, the so-called aromatic compounds, the simplest, and typical member of which is benzene, which has the empirical formula C_6H_6. A satisfactory structural formula for this substance was first given, in 1865,

[10]F. J. Moore, History of Chemistry, p. 173.

by Kékulé who assumed that the six carbon atoms are arranged in a ring, a single hydrogen being attached to each; and all the subsequent work on aromatic compounds has only served to confirm the usefulness of this hypothesis. One instance only can be mentioned here, namely, that whereas there is only one mono-substitution product, (i. e. where one atom of hydrogen is replaced by a different atom or grouping, as in phenol) there are three disubstitution products (designated as ortho, meta, para) which differ by reason of the different relative position of the two substituting groups. This will be evident from the structural formulae, as now written:



The long controversies which ended about 1860 in the triumph of Avogadro's hypothesis and the vindication of the atomic theory had been fought out in the organic field, and had culminated in the establishment of the valence theory as the guiding principle in that branch of the science. This gave, perhaps, to organic chemistry a somewhat exaggerated importance —at any rate, the idea that chemical compounds could be visualized as groups of real atoms united by real bonds exerted a remarkable fascination, and young chemists in great numbers began to devote themselves to synthetic studies, attempting on the one hand to prepare from the elements the most complex products of nature, and on the other to make the greatest variety of new combinations in order to find the utmost limits of chemical affinity and molecular stability. The rise of the coal-tar industry and the possibility of preparing from this source so many compounds of practical utility was partly cause and partly effect of this great movement which is going on uninterruptedly at the present day.

If, however, we ask what direct contribution *to the science as a whole* has been made by organic chemistry since 1860 we can hardly give it so high a place. We must rather confess that this branch of the science has lived largely for itself and while it has, during that time, developed a real history of its own which is of fascinating interest to the specialist, its great historical service to chemistry culminated in the work of Williamson, Gerhardt and Kékulé.[11]

(To be concluded)

[11]F. J. Moore, History of Chemistry, p. 212; italics mine.

HERMANN VON HELMHOLTZ[1]

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THE history of science concerns itself with the historical and logical sequence of scientific concepts. The process of development by which man arrives at fundamental laws of the universe in which we live is a vital study, having great possibilities for furthering the advance of science. Studies in this field have shown that the part of particular individuals, even men of great genius, is much less than is commonly supposed. Advance in science rests upon the work of many individuals whose observations and reflections cover rather long intervals of time. The genius is that fortunate individual who arrives upon the scene when the accumulation of observations enables the formulation of some general law for whose reception and acceptance the way has been prepared. The genius "reaps where others have sown"; the genius is great, as Newton intimated, because he stands upon the shoulders of giants.

Obviously only few men can be successful in attaching their names to fundamental laws. Prominent in this group is Hermann von Helmholtz, who in 1847 at the age of twenty-six, gave a complete statement of the law of the conservation of energy. Good fortune came his way in this law of energy and more than once again, but it must be said that Helmholtz met good fortune more than half-way, and entertained her so royally that no one could dispute his right to the visitation.

Helmholtz was favored, also, in living to see the law of the conservation of energy accepted as a truism, to see this law made the basis of the researches of hundreds of able scientists, and in being able himself to devote nearly half-a-century of vigorous intellectual activity to problems intimately connected with his first success. Towards the very end of his life in 1894, the great German was working upon the similar but more inclusive "principle of least action" which he hoped to extend mathematically so as to apply to all forces of nature.

Helmholtz applied rigorously to biological problems the methods of physical science and mathematical reasoning. His activity marks the beginning of the period in which philosophical speculation about

[1] A paper read at a meeting of the Research Club, University of Michigan, April 20, 1921, in commemoration of the centennials of Hermann von Helmholtz and Rudolph Virchow.

science was definitely superseded by experimental research in science, combined with mathematical treatment of the observations. The law of the conservation of energy was stated by him with a wealth of illustrations from mechanics, electricity, heat and biology, but it also included a mathematical formulation and discussion of the problem. In the study of physiological optics and of light, in the study of sound and harmony and the ear, in the study of the psychology of the senses, in the study of vortex motions, in the study of electrical phenomena and of physics generally, Helmholtz constantly reinforced experimental work with rigorous mathematical demonstration. Were one to attempt to characterize in a few words his extraordinary range of researches, one would say that Helmholtz brought biological and physical problems under the dominion of mathematical formulas and methods.

The rôle of the mathematical formulation and treatment of physical problems can not be overestimated. Kelvin, the intimate friend and active co-worker in science with Helmholtz, has stated: "All great scientific discoveries are but the rewards of patient, painstaking sifting of numerical data." With these data the scientist starts, making fundamental assumptions in the mathematical formulation of the problem. The successful formulation explains on the basis of the fundamental assumptions the observed facts; further than this, the procedure places the observed facts in harmony with other apparently widely-diverse phenomena, showing the harmony of natural forces and the reign of law in nature. But more than this the mathematical formulation suggests new facts of observation, and permits the prediction of observations which had previously escaped the observer. This is the peculiar merit, for example, of the Einstein theory, that it explains the facts of the Newtonian universe, explains certain facts which were in conflict with the Newtonian theory and enables the theorist to predict other natural effects not consonant with the Newtonian theory and hitherto unobserved. This type of mathematical ability Helmholtz had in a surprising degree, and it made possible his contributions to the advancement of science.

In a centennial recognition of a life of such great significance for mankind, the purpose is both historical and inspirational. What is the historical setting of the contributions of Helmholtz to civilization? What were the circumstances of birth and training, of academic position and environment, which made possible the wonderful productivity in apparently diverse fields of science? What can we do to foster the production of such men and to encourage this type of devotion to pure science? This brief survey of the life and activity of Helmholtz is prepared from the point of view of these questions.

Hermann von Helmholtz was born in Potsdam, August 31, 1821. His father was a teacher of philology and philosophy in the Potsdam

gymnasium, while his mother was a lineal descendant of William Penn. Despite a certain frailty of body his preparatory work included not only the traditional classical course with Latin, Greek and Hebrew, but also English and Italian, privately, with a beginning of Arabic, together with serious training in music. Even in the schoolroom he found further time for experimental work in physics and science. At the age of sixteen, although then desiring to devote himself to physics, he took an examination for a scholarship in the Royal Frederick William Institute of Medicine and Surgery, since the financial status of his family made desirable the election of the surer means of livelihood in medicine. One year later, Helmholtz entered upon the strenuous five year course of the institute. Here he completed the regular work, and studied, while acting as librarian, the works of Euler, Daniel Bernoulli, d'Alembert and La Grange. His thesis, "The Structure of the Nervous System in Invertebrates," contained the announcement that the nerve-fibers originate in the ganglion cells found by Von Ehrenberg in 1833; this discovery has been regarded by some physiologists as the histological basis of nervous physiology and histology.

For one year Helmholtz acted as house surgeon at the Charité in Berlin and then for five years at Potsdam as army surgeon as required of graduates of the institute. During these six years, he maintained active scholarly relationships with his teacher Müller, and with his intimate school friends, Brücke and du Bois Reymond, physiologists of later repute.

At this time the vitalistic theory was still dominant in physiology. Müller proposed the problem as to the nature of the vital force, whether self-engendered or similar to those of the inorganic world. This study of "vital forces" and the formulation given to the problem by Liebig, the chemist, stimulated the young student to several studies concerned with animal heat and with vitalistic problems. During these six years Helmholtz acquired further familiarity with mathematical physics and chemistry, made necessary by the problems he was considering. It was in this period, in 1845, that the Physical Society was founded by du Bois Reymond, Brücke, Karsten, Knoblauch, Beetz and Heintz, and Helmholtz became one of the most active members with many contributions, published in the *Fortschritte der Physik*.

On July 23, 1847, Helmholtz read before the Physical Society his paper, "Die Erhaltung der Kraft." This paper was offered to Poggendorff's *Annalen*, but rejected by Gustav Magnus, the physicist, since he regarded experimental and mathematical physics as separate departments. In fact, Magnus warned Helmholtz "against undue partiality for mathematics, and the attempt to bring remote provinces of physics together by its means."

Despite the peculiar objection of Magnus, unfortunately shared

by many physicists of that day, the article was published and received the enthusiastic support of a chosen few who recognized the relationship to the work of earlier mathematical physicists.

In 1848, Helmholtz received the appointment as lecturer in anatomy at the Academy of Art and assistant in the Anatomical Museum of Berlin, in recognition of his researches, and a year later was called to Königsberg as professor of physiology.

In 1885, Helmholtz became professor of anatomy and physiology at Bonn, where he remained but three years, being called in 1858 to Heidelberg as professor of physiology. In 1871, at the age of fifty, he received the call as professor of physics to Berlin, having at that time incidentally made contributions to physics comparable in both range and worth with those made by any other physicist of the same period. In 1888, Helmholtz was relieved of teaching to devote himself entirely to the Physico-technical Institute of Berlin of which he became the first president. In this office the great scholar continued until his death in 1894.

The first fruits of his lectures at Königsberg on the physiology of the sense organs was the invention, late in 1850, of the opthalmoscope, an instrument which renders it possible to examine the retina of the living eye. Helmholtz says:

> While preparing my lectures I hit upon the invention of the opthalmoscope, and then on the method of measuring the velocity of nervous impulses. The opthalmoscope became the most popular of my scientific achievements, but I have already pointed out to the oculists that good fortune had more to do with it than merit. I had to explain the theory of the emission of reflected light from the eye, as discovered by Brücke, to my students. Brücke himself was but a hair's breadth off the discovery of the opthalmoscope. He had only neglected to ask himself what optical image was formed by the rays reflected from the luminous eye. For his purpose it was not necessary to put this question. Had it occurred to him, he was just the man to answer it as quickly as I, and to invent the opthalmoscope. I was turning the problem over and over, and pondering the simplest way of making it clear to my audience, when I came on the further issue.

The opthalmoscope established the position of Helmholtz in the scientific world. More than that, opthalmic medicine had a new birth with this instrument and with the opthalmometer which Helmholtz perfected for measuring the physical constants of the eye. Many students were drawn to this field, although his description of the opthalmoscope, published in 1851, was somewhat slow in general acceptance because of the mathematical and physical knowledge pre-supposed. Helmholtz himself stated:

> I attribute my subsequent success to the fact that circumstances had fortunately planted me with some knowledge of geometry and training in physics among the doctors, where physiology presented a virgin soil of the utmost fertility, while, on the other hand, I was led by my acquaintance with

the phenomena of life to problems and points of view that are beyond the scope of pure mathematics and physics.

With both the opthalmoscope and the opthalmometer, thorough familiarity with mathematical physics was absolutely essential in the theory and construction of the instruments.

His inaugural lecture "on the nature of human sense-perceptions" was delivered at Königsberg on June 28, 1852. This discussion involved, in connection with the study of sensations of sight, problems of the theory of knowledge; it also involved an exposition of the undulatory theory of sound and light, including the statement that light rays and heat rays are identical, impinging on two different kinds of nerve end organs.

For more than fifteen years, Helmholtz worked intensively on physiological optics and his "Handbuch der Physiologischen Optik" (1856-66), marks an epoch in the physiology of the eye, in the physiological-psychology of sensations and perceptions of sight, and in the physical theories of light and color. To-day the current issue of the "Handbuch" is published with four editors to present adequately the varied fields mentioned. To particularize further his numerous contributions to optics would take more time than is at my disposal. It may be of interest to the many sufferers from astigmatism to know that this condition was discovered by Helmholtz with his opthalmometer; the defect is that the cornea and crystalline lens are not accurately centered, preventing the sufferer from seeing vertical and horizontal lines with equal clearness at the same time.

The "Handbuch der Physiologischen Optik" will long remain as one of the most noteworthy contributions made to physiological psychology, not alone from the strictly physiological and the psychological sides, but quite as much because of the comprehensive grasp of geometrical and physical properties of light and lenses as related to the physiological structure of the eye and the sensations communicated to the brain.

The notion that sensations of light and color are only symbols for relations of reality, giving no knowledge of the real nature of external phenomena, was one fundamental conclusion of these researches on optics. The wide interest in this subject induced Helmholtz to investigate the subjectivity of sensation for the other senses, beginning with acoustics. In this field the physicist, Ohm, has suggested "that the ear analyses and hears the motions of the air in exact correspondence with Fourier's series." This theorem of Fourier states that any periodic function of a variable may be expressed as the sum of periodic sine functions, of x and integral multiples of x, or, in other words that any repeating wave form may be decomposed into a number of simple waves of different length, the longest of the same length as the given

wave and the others of one half, one third, one fourth, and so on, integral portions of this length. This application of a mathematical theorem to a physiological process was in such harmony with the preceding work of Helmholtz that no surprise is occasioned by his extension and development of the idea. Particularly the application of this theory to harmony was an outstanding contribution made by Helmholtz. Consonance, he taught, is produced when the ear perceives as a continuous sensation tone movements that are regularly repeated at given intervals; on the other hand, discontinuous sensation gives dissonance. Mathematically he demonstrated that vibrations in the ratio of small integers give rise to movements regularly repeated. The place of resonance and of the upper partial tones in the theory of consonance and of sound was definitely established by mathematical methods with most ingenious mechanical devices for making these upper partials evident to an observer. So far as the physiological structure of the ear is concerned, his theory was that the fibers of the basilar membrane act like the strings of a piano, and furnish the instrument of analysis into simple tones. Here, in this field the text-book which he wrote was again the result of a series of contributions to the theory of sound, based commonly upon mathematical formulation of the problems involved.

In mathematical physics proper, probably the most noteworthy contribution is that of 1857 "On the integrals of the hydrodynamic equations which express vortex-motion." The treatment both from the mathematical and the physical point of view is still fundamental in the discussion of the motions of fluids. Another paper of 1859 treats "the theory of aerial vibrations in tubes with open ends," in which from purely theoretical considerations he deduces the relations between the plane waves of the tube and hemispherical waves that spread from the tube, solving the problem of the influence of the open end upon the sound and determining the necessary lengths[2]. Kelvin elaborated the theory of vortex motion, the indestructibility of the vortex furnishing an approach to a theory of the constitution of the matter.

The electrical researches of the later years came at a period when fundamental changes in point of view were preparing. Helmholtz had accepted and furthered Maxwell's electro-magnetic theories and his gifted pupil, Hertz, achieved the experimental confirmation of the Maxwell theory, leading to the development of wireless telegraphy. Helmholtz was not only receptive to the new ideas, but active in their

[2]It is of some interest to know that Steinway worked in the laboratory of Helmholtz during the time of Helmholtz's researches on sound. One of our own Michigan professors, Watson, the astronomer, sat on the jury of award at the Paris Exposition where the Steinway piano was given first place largely because of its superiority from the scientific standpoint. (This note is supplied to the writer by Professor A. A. Stanley.)

dissemination. In his Faraday lecture of 1881, he definitely propounded the atomistic theory of electricity now commonly accepted, which is intimately connected with fundamental chemical problems. Several studies on the thermodynamics of chemical processes followed, and the Helmholtz-Gibbs equation is to-day the fundamental theorem in this field.

Helmholtz recurred so frequently in popular lectures and in scientific papers to the conservation of energy that it seems desirable to discuss the historical setting of this contribution. Particularly also, since an acrid controversy arose over the question of priority in statement. Englishmen to-day commonly credit an Englishman with the first statement, while the Germans, with better right in this case, credit a German, Robert Mayer. This arouses popular interest; many more people can comprehend the theft of an idea than can comprehend the idea. Particularly to follow the genesis of an idea requires a certain concentration which is not popular.

At the time of Helmholtz, the indestructibility of matter was accepted, apparently first started by Huygens, (1629-95). The Academy of Sciences at Paris had declined to receive any further attempts at perpetual motion since they assumed that energy could not be created. Huygens even made a general statement, in his treatise on light, that true philosophy is that "in which one conceives the cause of all natural effects as mechanical." So far as heat and energy are concerned, it is true that at this time many scientists still considered heat as a substance. However, Rumford, in 1798, showed definitely by observations on the boring of cannon that the substance theory was not tenable; Sir Humphry Davy, in 1799, clinched the argument of heat generated by friction by rubbing two pieces of ice together and generating sufficient heat to melt the ice. With Carnot, in 1824, heat was definitely recognized as a form of energy, and Clapeyron, writing in 1834 in the *Journal de l'école polytechnique* reprinted in 1843 in Poggendorff's *Annalen*, states definitely that a quantity of heat and a quantity of work are "magnitudes of like nature and that it is possible to substitute the one for the other."

The possibility of the universal application of these and other related facts to the whole field of energy was seen almost simultaneously by different observers. Robert Mayer, a German physician located in a small village, was certainly the first of this period, in 1842, to make the general statement in a paper "On the forces of inorganic nature," and he had it at first rejected by physicists of repute, and unnoticed after publication. Joule, a brewer scientist of England, in 1843 presented before the British Association a paper in which he gave the mechanical equivalent of heat, and studied relationships between electrical and chemical and mechanical effects, while in 1847, he gave the com-

plete formulation of the principle of the conservation of energy. The formulation by Helmholtz came at a more fortunate time and place, with a richer presentation involving mathematical investigation of the fundamental considerations. But the priority of Mayer can not be disputed; nor can one dispute the great value of Joule's determination of the mechanical equivalent of heat.

A general idea of such wide significance is only possible because it is, more or less, "in the air." The idea is of value because it is definitely related to the past and to the present; the great idea must be capable of appreciation by an active group of intellectual workers, and this appreciation is only possible for an idea which has had some orderly process of growth.

Helmholtz assumes that all problems of natural science can be reduced to "unchangeable, attractive and repulsive forces whose intensity depends upon the distance. The solution of this problem is the condition for complete comprehension of nature." This assumption has within ten years been definitely rejected. Notably Albert Einstein, in a paper on "Theoretische Atomistik," and Max Planck, in a paper on "Das Prinzip der Kleinsten Wirkung," reject this conception, while retaining the greater part of the theoretical achievements of Helmholtz in his conception of the conservation of energy and the principle of least action.

Helmholtz, it should be noted, resolutely set himself against any commercialism or financial exploitation of his researches. His words on this subject are worthy of serious consideration to-day in every great American university, where in some departments a tendency exists to mix devotion to science and learning with devotion to private interests. Helmholtz says: "Whoever, in the pursuit of science, seeks after immediate practical utility may generally rest assured that he will seek in vain, . . . we must rest satisfied with the consciousness that he too has contributed something to the increasing fund of knowledge on which the dominion of man over all the forces hostile to intelligence reposes."

Helmholtz was always one of the leading figures in the academic communities in which he worked. In the German universities of that day, as in the English and European Universities of to-day, the productive scholar was given the tribute of popular recognition. No administrative officers, neither presidents nor deans, nor bursars nor secretaries, served to divert student and popular attention from the men who made the university a place of learning. In fact, the attitude towards scholarship was such that political office was tendered to Helmholtz, and every recognition the state could bestow upon an individual was given him.

One concession Helmholtz made to this popular interest, which

should also be seriously considered by American scholars, particularly in our great universities. Helmholtz prepared popular expositions for general audiences of the results of his own and allied researches. These popular expositions attracted in print a great circle of readers, undoubtedly contributing to a wider appreciation and understanding of the methods and aims of science. This type of activity, so much neglected in our own universities, should be, as a university matter, a concern of the Research Club. Now it is only a matter of accident, if students of this university and citizens of this state learn what are the real contributions to human progress made within the walls of this institution. Not otherwise can a wider appreciation for true science be obtained than through the active cooperation of productive scholars.

In closing, I wish to point out how easily a man's life may be given a false interpretation by apparently competent observers. No less able a writer than W. K. Clifford states of Helmholtz that in studying the eye and ear "he found it was impossible to study the proper action . . . without studying also the nature of light and sound, which led him to the study of physics; he is now one of the greatest physicists of the century . . . . He then found it was impossible to study physics without knowing mathematics; and accordingly, he took to studying mathematics, and he is one of the most accomplished mathematicians of this century." This statement is both false and pernicious; and yet has received wide circulation and recognition. False it is because at the age of 26, and continuously for many years thereafter, Helmholtz demonstrated himself to be one of the great mathematical physicists of the world, having devoted many years to mathematical training. Pernicious it is because students are led to suppose that in later years they can atone for the neglect of their youth, and study fundamental subjects as the need arises. Helmholtz is a shining example of a man well prepared in fundamentals, whose preparation made possible for him the mathematical formulation and investigation of problems not before subjected to this analysis. His complete command of the tools prepared by mathematicians and physicists of preceding ages made Helmholtz a great contributor to modern civilization.

RUDOLF VIRCHOW—PATHOLOGIST[1]

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IN his delightful autobiography, the elder Gross[2] writes of his first European visit in 1868.

There were three professional men in Berlin whom, as their names had long been familiar to me as household words, I was most anxious to see—Virchow, Langenbeck and Graefe. Accordingly, early in the morning of the second day after our arrival, I went to the Allgemeines Krankenhaus in search of Virchow, the illustrious pathologist and accomplished statesman, a professor in the university of Berlin, and a member of the German parliament. The great man, upon my entrance, was in the midst of his pupils, engaged in a post-mortem examination. As my presence attracted some attention, ... I deemed it my duty, although the moment was not the most opportune, to pass my card to the professor, at the same time apologizing for the intrusion. He at once saluted me with a gracious bow, and, shaking me cordially by the hand, introduced me to his pupils and expressed his gratification at seeing me. After a few minutes spent in conversation, he resumed his knife and completed his examination. He showed me his laboratory, his lecture-room, and many of his more interesting pathological specimens, most of them prepared by his own hands. His collections of diseased hearts of children, the result of inherited syphilis, is the largest in the world, and, as he explained specimen after specimen, he became not only enthusiastic but eloquent . . . . The laboratory, or work-shop as it may be termed, of Professor Virchow is a model in its way, admirably adapted to the wants of the student for improvement in the use of the microscope and the examination of morbid specimens. . . . Microscopes are provided in great numbers, and, in fact, every facility is afforded for the acquisition of knowledge. . . . . Such a room with the necessary appliances ought to exist in every well-organized medical institution in the United States.

Dr. Gross died in 1884, so that he lived to see but the slightest realization of this wish, which has now reached a degree of fulfilment beyond the greatest anticipation either of Virchow himself or of his contemporaries.

To continue Dr. Gross's personal narrative—and I can do no better in order to give an intimate acquaintance with him whose centennial we celebrate:

[1]A paper read at a meeting of the Research Club, University of Michigan, April 20, 1921, in commemoration of the centennials of Hermann von Helmholtz and Rudolph Virchow.

[2]Autobiography of Samuel D. Gross. G. Barrie, Philadelphia, 1887. Vol. 1, p. 231-235.

Virchow is a most patient and laborious investigator and yet he never seems to be in a hurry. His dissections [autopsies][3] seldom occupy fewer than two and a half or three hours each. Every organ of the body is thoroughly explored. For years past his habit has been to open, every Monday morning, a cadaver in the presence of his private pupils with a view of instructing them in the art of conducting autopsies—holding the knife, using the saw, and taking notes, the whole being supplemented by microscopic inspections of the more important diseased structures. In these dissections he is, if possible, more patient even than Rokitansky, his great Viennese prototype.

Virchow is a thin, slender man, about the medium height, with a fine forehead, although the head is not large, and handsome black eyes, concealed by a pair of glasses. He is deliberate in his movements, a good talker, very affable, courteous and warm-hearted—in a word, a gentleman of the higher type.

The evening before Dr. Gross left Berlin he had further occasion to appreciate Virchow's splendid courtesy. While he was the guest of honor at Virchow's own table, together with von Langenbeck, von Graefe, the oculist, Donders, Gurlt and others, the host drew from under the table a large book, which proved to be the second edition of Gross's "Elements of Pathological Anatomy," and, rising, took his guest by the hand and in a graceful speech referred to the text as one from the study of which he had derived much useful instruction and one which he always consulted with much profit.

American medicine has too seldom received that full appreciation in Berlin and Vienna that Virchow was always willing to give. In reviews and abstracted articles edited by him one is struck by the large number of English and American references included.

Nearly twenty years after the visit of Gross to Berlin, we find Sir William Osler a pilgrim in Virchow's laboratory. Perhaps it has been the growing breadth of vision during those years, but not unlikely it is the wonderful catholicity of interests, possessed by the great visitor himself which changes the character of the pen picture. Part of his narrative I must reproduce even though it reaches beyond the limits of my subject. Osler[4] writes:

In 1884, on returning to Berlin for the first time since my student days, I took with me four choice examples of skulls of British Columbian Indians, knowing well how acceptable they would be. In his room at the Pathological Institute, surrounded by crania and skeletons, and directing his celebrated *diener,* who was mending Trojan pottery, I found the professor noting the peculiarities of a set of bones which he had just received from Madeira. Not the warm thanks, nor the cheerful, friendly greeting which he always had for an old student, pleased me half so much as the prompt and decisive identification of the skull which I had brought, and his rapid sketch of the cranial characters of the North American Indian. The profound expert, not

[3]Bracketed words are inserted by the author.

[4]Osler, William. Virchow, the man and the student, Johns Hopkins University Circulars, 1891, XI, 17-20.

the dilettante student has characterized all of his work in this line . . . As an illustration of his capacity for varied work, I recall one day in 1884, in which he gave the morning demonstration and lecture at the Pathological Institute, addressed the Town Council at great length on the extension of the canalization scheme, and made a budget speech in the House, both of which were reported at great length in papers of the next day.

Rudolf Virchow graduated in medicine from the Friedrich-Wilhelm Institute in 1843 with the dissertation *De rheumate praesertim corneae*. In the autumn of 1844, he became an assistant in pathological anatomy under Froriep, and in 1846 he was appointed prosector in the same clinic. He became a lecturer in the University of Berlin in 1847. Possessing vigorous political views, which would be considered liberal even today, he lost his university connections during the stormy period of 1848 and 1849, largely through the publication with Leubuscher of a half-medical, half-political journal, which they styled *Medicinische Reform*. From 1849 to 1856 he occupied the chair of pathological anatomy at Würzburg, where, working with the greatest industry, he raised his department to foremost rank and pursued investigations upon which much of his later work was based. At the end of that period, he was recalled to Berlin as professor of pathological anatomy and director of the newly established pathological institute in Berlin University, with which he was connected until his death.

To understand Virchow's relation to pathology and to medicine is to understand something of the stages through which scientific medicine has passed in the last one hundred and fifty years. We are now, and have been for some fifty years, in a period characterized by search for the etiological factor in disease. In part, the bacteriologist has been in the ascendency and we already have sufficient perspective to see the greatness of Pasteur and Koch. Among our contemporaries there may be those equally to be honored by another generation. Moreover, there are those who would have us believe that we are even now passing from the epoch of bacteriology into a period dominated by biochemistery, serology and immunology, but upon this transition, if, indeed, it should be dignified as such, light is still to be shed.

At any rate, these present-day tendencies will serve to illustrate the shifting emphasis in medical progress. Does it mean that the stage has been set for a certain scene, or that a brilliant and indefatigable worker, inspiring a group of collaborators, strides off into the unknown? As we read current medical history, the advance appears to be gradual and simultaneous along interdigitating lines. In retrospect, the advance assumes the topography of a series of steps rising from plateau-like surfaces. The highest step of the nineteenth century was the rise of microscopical pathology as established and developed by Rudolf Virchow.

Cellular pathology rose from a foundation of gross pathology. In the later half of the preceding century John Hunter had developed his wonderful museum of gross preparations of both normal and pathological anatomy. He had had the hardihood to apply objective experimental methods to the investigation of pathological problems. Through the experimental production of arterial anastomoses, he found that it was possible to ligate arteries whose flow had previously been considered essential to the life of a part. For Hunter, Virchow had the greatest admiration, and it has been said that for a long time Hunter's picture alone was found upon the walls of his laboratory. Fifty years or so after Hunter, Rokitansky in Vienna brought the period of gross pathology to its greatest height. The first autopsy protocol written in his own hand is dated October 23, 1827. In March, 1866, he achieved his thirty thousandth post-mortem examination. It is said that before his death he had access to 100,000 protocols of autopsies done by himself and his assistants. With this enormous material he brought descriptive gross pathology to a degree of perfection never before realized.

As will be noted by the dates just given, Rokitansky was well established in his field of gross pathology when Virchow read his inaugural dissertation. In fact, Virchow was still in his assistantship when the first volume of Rokitansky's *Lehrbuch der pathologischen Anatomie* appeared in 1845. With the microscope at his disposal, his independence of thought, his originality in attack, and, above all, his ability to exalt pure objective description as an end in itself made it possible for Rudolf Virchow to do for the pathology of the cell what Rokitansky had done for the pathology of the organ and tissue.

All medicine before Virchow had been burdened with mysticism, dogma and hypothesis. Witness the pertinacity with which the humoral theory survived in its varying forms, even to the extent of obscuring the earlier part of Rokitansky's work. All this Virchow was able to cast aside and, avoiding dogma, he developed a method rather than a theory.

To those who would lessen the importance of Virchow's work by reference to Bichat, it need but be said that while the latter did resolve the various organs and tissues of the body into twenty-one simple, and, as he supposed, elemental types, this analysis was done on the basis of naked-eye observation alone. Bichat did not use the microscope. Like Virchow, however, he placed the objective detailing of facts before speculation. To Schleiden and Schwann, Virchow gave full credit for the earlier development of the idea of the animal cell as interpreted in terms of cellular botany. Yet, it must be remembered that to a great extent Virchow was called upon to formulate for himself standards of normal histology as well as to describe the changes produced in the cell by disease.

No adequate analysis of Virchow's published work can be given here. Its volume is remarkable. In 1901, Schwalbe[5] and others whose assistance he invited, compiled a Virchow bibliography as their part in the celebration of the eightieth birthday of their old master. In the preface, Schwalbe himself says that a Virchow bibliography lays bare not alone the life-work of a man, but exposes as well a history of medicine and anthropology for the preceding sixty years. Requiring 118 pages, with an average of about eighteen items to the page, this list of approximately 2,000 titles bears witness to the industry, breadth of interest and critical scientific discrimination of the cellular pathologist. From all of this material I can refer only to the two most important books, to the journals developed under his leadership and to a few of the most important articles.

"Die Cellularpathologie" appeared in 1858. This book, presented in the form of twenty lectures illustrated by numerous wood cuts, placed before the world for the first time a summation of the author's views. Here was demonstrated that the principle of *omnis cellula e cellula*, which he was first to put into words, applied equally to pathological formations and to normal embryologic development. Translated into French by Picard and into English by Frank Chance, "Cellular Pathology" was seized upon with an avidity which must have surprised even its author. From that year modern pathology is to be dated. We cannot appreciate the effect upon Medicine of this new point of view. Before, all morbid products, tumors, cancers, purulent collections, tubercles, gummas had been explained as arising in, or from, a hypothetical primitive blastema, itself exudative in nature. Now these were shown to be composed of living body cells, differing in various ways from the normal, exhibiting alterations both in form and function. With histological technique in its infancy, much was incomplete and misinterpretations were bound to occur, even as they do to-day.

Let me illustrate the accuracy of observation shown in the "Cellular Pathology" by quotations dealing with the subject of argyria, the deposit of silver pigment in the tissues. Every student of pathology now knows that argyriasis shows a selective affinity for the fibrillae of connective tissue. Silver is not deposited in epithelial structures, although it usually gains entrance to the body by passing through an epithelium. Note how clearly Virchow states these facts.

> We know that when any one takes salts of silver, they penetrate into the different tissues of his body. . . . A patient who had . . . received a solution of nitrate of silver as a lotion [for the eyes], very conscientiously employed the remedy . . . ; the result of which was that his conjunctiva

[5]Schwalbe, J. Virchow-Bibliographie, 1843-1901. G. Reimer, Berlin, 1901. Pp. 183.

assumed an intensely brown, nearly black appearance. The examination of a piece cut out of it showed that silver had been taken up into the parenchyma, and indeed in such a manner that the whole of the connective tissue had a slightly yellowish brown hue upon the surface, whilst in the deeper parts the deposition had taken place only in the fine elastic fibers of the connective tissue, the intervening parts, the proper basis-substance, being perfectly free. But deposits of an entirely similar nature take place also in more remote organs. Our collection contains a very rare preparation from the kidneys of a person who on account of epilepsy had taken nitrate of silver internally. In it may be seen the Malpighian bodies, in which the real secretion takes place, with a blackish blue coloring of the whole of the membrane of the coil of the vessels, limited to this part of the cortex, and appearing again, in a similar, though less marked form, only in the intertubular stroma of the medullary substance. . . . . The salts of silver do not deposit themselves in the lungs [when present in the circulating blood], but pass through them to be precipitated only when they reach the kidneys or the skin.

Taking second place in importance among the larger works of Virchow, is the three volume treatise on tumors, "Die Krankhaften Geschwülste." This was completed in the years 1863-1867. In it Virchow develops a systematic classification of neoplasms based largely upon their microscopical characteristics. Here the influence of his teacher, Johannes Müller, is evident. The terminology used by Virchow in this work still survives to a large degree.

Of the great array of lesser works, I can mention but a few groups. In the late forties Virchow, published a series of epoch-making papers on disturbances of the circulation. Here for the first time phlebitis, thrombosis, metastasis and embolism were clearly set forth. In fact, the term Embolia, or as we now say, embolism, was introduced by Virchow himself. Osler relates that in 1848, at the height of Virchow's political activity, he performed an autopsy upon a patient, said by Schönlein to have died from cerebral hemorrhage. Virchow found no hemorrhage, but succeeded in demonstrating an embolus blocking an important cerebral artery. Schönlein, who was present to see the outcome of his diagnosis, turned to Virchow and in a half-joking, half-vexed manner, said *Sie sehen auch überall Barricaden.* Other important monographs, papers and groups of papers were those dealing with calcium metastasis, pathological pigmentation, amyloid, leukaemia, chlorosis, phosphorus poisoning, syphilis, trichinosis, rickets, cretinism, encephalitis and peptic ulcer. The list might be much extended.

In 1847, Virchow with Reinhardt founded the *Archiv für pathologische Anatomie und Physiologie und für klinische Medicin.* This journal has been continued since that time, and constitutes the most important collection of original contributions to scientific medicine. After Reinhardt's death in 1852, Virchow carried the editorship alone for many years, so that even now one finds as many citations to this journal by the phrase "Virchow Archiv" as by its proper title. From 1851 to 1893

he was the joint editor, and from 1893 to 1901 the sole editor, of Canstatt's *Jahresbericht über die Leistungen und Fortschritte in der gesammten Medicin.* From 1850 to 1862, Virchow shared with Kölliker, Scherer and Scanzoni the editorship of the *Verhandlungen der physikalisch-medicinischen Gesellschaft in Würzburg.*

A list of Virchow's pupils would include most of the makers of medicine of the last fifty years. Scattered throughout the civilized world, they have from time to time brought together in *Festschriften* and memorial celebrations lists of names and collections of original contributions of which their old master may well have been proud. The *Festschrift* for his seventy-first birthday contributed by his former, and then acting, assistants in the Berlin Pathological Institute includes in its table of contents the names of v. Rechlinghausen, Klebs, Salkowski, Orth, Grawitz and Langerhans, among others, all of whom have had a great influence on the development of pathology and modern medicine. American medicine owes much to those who were under Virchow's tutelage in the last three decades of the nineteenth century.

Virchow was wrong. The cell is not the ultimate unit of life, but the methods of cellular pathology have grown no less important since he gave his great work to the world. The cell with its miscroscopically demonstrable content is still the morphological unit of life. Disease processes are still interpreted in the light of the cellular changes.

To Virchow we owe our conception of disease. Disease is not an entity, entering the body from without. Disease is life, life which deviates from the normal. The casual factor may reside within or may come from without in the form of trauma, infection, intoxication, or what not, but the cause is not the disease. The disease is the abnormal life of the body cells. The methods of modern medicine are therefore broadly biologic, and along this road of promise Rudolf Virchow pointed the way.

RUDOLF VIRCHOW—ANTHROPOLOGIST AND ARCHEOLOGIST[1]

By Professor ARTHUR E. R. BOAK
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RUDOLF LUDWIG KARL VIRCHOW was born in the little Pomeranian town of Schivelbein, on October 13, 1821. He died on September 5, 1902. His parents were people in moderate circumstances, his father combining the occupation of a farmer with that of a retail merchant. The young Virchow received his early education at the parochial school of Schivelbein, with special instruction from the local clergymen. He then entered the gymnasium at Köslin, from which he graduated in 1838 at the age of seventeen.

At the gymnasium he followed the regular classical program of studies, but showed at the same time great enthusiasm for the natural sciences, history and geography. He acquired and retained throughout life a remarkable accuracy in both Greek and Latin, and in his later years upon several occasions mercilessly criticized the barbarisms which the younger generation attempted to introduce into medical terminology. This same attention to accuracy of details characterized Virchow's work in every field, and gave him the perfectly astounding mass of information which rendered him such a deadly critic of unstable hypotheses. In addition to the study of the classics, Virchow found time at the gymnasium to read widely in the French and German classics. Italian and English he acquired later. It is interesting to have his reflections upon suitable courses of study for the gymnasium, expressed in an address delivered when rector of the University of Berlin. He maintained that, as a preparation for scientific work, a course in mathematics, philosophy and the natural sciences would have equal value with a classical course, but that the later could not be replaced by the modern languages.

From the gymnasium at Köslin, Virchow proceeded to the Royal Medico-Surgical Friedrich Wilhelm's Institute at Berlin. Here he qualified for the doctorate in 1843. In connection with his inaugural dissertation, Virchow defended, among other theses, two which he afterwards looked upon as showing the early ripeness of his intellect and the breadth of his interests. The first of these ran *nisi qui liberali-*

[1] A paper read at a meeting of the Research Club, University of Michigan, April 20, 1921, in commemoration of the centennials of Hermann von Helmholtz and Rudolph Virchow.

bus rebus favent veram medicinae indolem non cognoscunt (Those who do not encourage progress do not grasp the true nature of medicine); the second was an application of Agassiz's then recently published glacial theory to Pomerania *Pomeraniae petrificata glacie primordiali disiecta.* To Virchow there might fittingly be applied the saying, *homo sum, et nihil humanum mihi alienum puto.* His ability to connect science with life as a whole and his interest in everything pertaining to life led him from the investigation of the dead to that of the living man, from craniology to ethnology and to the history of civilization, as well as from the laboratory into the political arena.

In full conformity with this atitude towards life was Virchow's report upon the typhus epidemic in Silesia, published in 1848. Here he showed that the source of the epidemic was to be found in the backward social and political conditions of Silesia, and made radical suggestions for their amelioration. The championship of the people which he thus assumed he maintained throughout a long political career, as a member of the Prussian House of Representatives, from 1862 to 1878; of the Reichstag, from 1880 to 1893; and of the municipal council of Berlin for 42 years. He was a founder of the progressive party (*Fortschrittspartei*), and a firm opponent of Bismarck's imperialism, being honored by the latter with a challenge to a duel. He fought unceasingly for the improvement of the education as well as the social conditions of the masses, and the term *Kulturkampf* was an outgrowth of his political manifestoes. But, at the close of his life, it was Virchow's boast that, although he had devoted himself to both politics and medicine, he had always succeeded in preserving for science its independence of political influences.

While a professor at the University of Würzburg (1849-56), Virchow published two studies on cretinism in Lower Franconia and pathological skull forms (1851-2). These may be taken to mark the beginning of his anthropological work, and were the first of more than one thousand publications in this and allied fields. They were followed (1857) by his "Investigations on the Development of the Base of the Skull in Healthy and Diseased Conditions, and on the Influence of the same upon Skull Form, Facial Structure and Brain Formation." In this treatise he laid the foundation for an anatomical treatment of craniology, pointing out as the problem for investigation the relationship between the shape of the skull, the facial structure and the formation of the brain. His conclusion was that all typical variations in facial structure rest chiefly upon differences in the formation of the base of the skull.

For about a decade following his return to Berlin in 1856, Virchow's main interest and activity lay in the field of medicine. Then he began to turn his attention in an ever increasing degree to anthropological and allied studies, upon which he entered with all the enthusiasm of a true

pioneer. In 1869, mainly through his efforts, was organized the Deutsche Anthropologische Gesellschaft. In the same year he founded the Berliner Gesellschaft für Anthropologie, Ethnologie und Urgeschichte, and its organ the *Zeitschrift für Ethnologie*. In addition to directing the publication of the *Zeitschrift*, he was also an editor of the *Correspondenzblatt* of the Anthropologische Gesellschaft and, from 1870, of the *Archiv für Anthropologie*. The degree to which these new fields absorbed Virchow's activities may be gathered from the fact that, although it was as a pathologist that he was elected to the Royal Academy of Sciences at Berlin in 1874, only three of his numerous papers read before the academy dealt with problems of pathology, while nearly all the rest discussed anthropological subjects.

Passing from the study of the diseased to that of the normal skull, in 1874 Virchow presented the results of his attempts to find ethnognomic skull characteristics in an article entitled "On Some Characteristics of the Skulls of the Lower Races of Man." Here he advanced the generally accepted view that the frontal projection of the squamous portion of the temporal bone is a pithecoidal characteristic, much more frequent among non-Aryan than Aryan peoples; and that the unproved, but certainly to be suspected, defective formation of the temporal brain parts as a result of this frontal projection permits us to see in the latter, and in the bare narrowing of the temporal area, a mark of lower, but not necessarily of the lowest, races.

Virchow's next efforts were directed towards the determination of the skull types of European races. Here the prevailing view was that of Retzius: that each of the great racial divisions had a single type of skull and that peoples must be differentiated as either dolicocephalic or brachycephalic. Virchow took a more cautious attitude and opposed the selection of type skulls "until the whole breadth of individual varieties was known." He also combatted Nilson's theory that an original brachycephalic European population had been overrun by a dolichocephalic element which stood upon a higher plane of physical and mental development, *i. e.*, the Celts and the Germans.

In 1875, Virchow declared it impossible to establish definite craniological types for Germans, Celts, Slavs, Finns or Italians; that the postulate of originally pure and homogeneous great culture races is erroneous, and that all these have been formed by a mixture of smaller elements, a view which now receives general acceptance. Then, in the following year, in his "Contributions to the Physical Anthropology of the Germans," he claimed that even greater weight should be laid upon the height of the skull than upon its length or breadth, and he was able to show that the old German cranial type, as represented by the Frisians, were chamaeprosopic and mesocephalic rather than dolichocephalic as had been maintained heretofore.

The scope of Virchow's anthropological studies widened until he sought to give an exact descriptive basis for the natural history of man. Hence he directed his investigations toward living peoples, as well as toward those which are now extinct, and entered upon the field of ethnology. One great result of his efforts was the census of the school children of the German Empire, taken from the point of view of racial physical characteristics. This census brought out the fact that the historic characteristics of the old Germanic type—blond hair, white skin and blue eyes—were to be found united in only approximately one third of the population of Prussia and one fifth of that of Barvaria. Perhaps in this connection one should mention Virchow's establishment in 1888 of the Museum for German National Costumes and Products of Household Industry, at Berlin.

Carrying his investigations outside of Germany, Virchow compiled anthropological analyses of the Lapps, Eskimos, Patagonians, Terra del Fuegians, Kaffirs, Australians and Malays. One of his most interesting studies was that of the population of Ceylon, in which he established the nanocephalism and racial purity of the Veddas, as well as their relationship to the older Dravidian or pre-Dravidian population of India, while showing that the Cingalese, on the contrary, were a mixed race.

Virchow continued his craniological studies with unabated zeal until the time of his death, when his collection comprised some 4,000 skulls, ancient and modern, coming from all quarters of the globe. Yet he had to acknowledge his inability to attain a satisfactory craniological differentiation of races, or an explanation of how various skull types arise among the same people. He gave great attention to the development of more exact methods of craniological measurements, and helped to bring about the adoption of standard systems in this field. Another beneficial result of his work in this field was the exclusion of pathological forms from the list of skull types. Here it may be mentioned that he maintained that the celebrated Neanderthal skull exhibited pathological characteristics, and consequently protested against the acceptance of a distinct racial type upon the evidence of this single specimen. But in this he failed to win the support of the majority of anthropologists.

In addition to studies upon Illyrian, Trojan, Cyprian, Moroccan, East African, Ancient and Modern Greek, and Philippine skull types, Virchow published a work on American racial skulls—Crania Ethnica Americana—noteworthy both for its descriptive details and for its differentiation of pathological deformities of the skull from artificial deformities resulting from accident or intent. His examination of the remains of the Java ape-man—*pithecanthropus erectus* Dubois—led him to the conclusion that it did not belong to the genus homo, but was a gibbon of an extinct species, a view which now finds little acceptance.

It was inevitable that Virchow should be attracted by the basic problems of anthropology and biology, such as the origin of species and the place of man in the natural world. And it was natural that his point of view in these questions should depend upon his belief in the identity of physiological and pathological processes. His formula was: Individual and type equal pathology and physiology. Towards the Darwinian theory of evolution he was by no means hostile, but exhibited the same cautious attitude as in other anthropological questions. He held that there was a great gap in our knowledge, namely, in regard to the development of the human from the lower forms of life. For the time this gap may certainly be filled by an hypothesis, for only by hypotheses can the path of research in unknown fields be marked out. Such a hypothesis, Virchow felt, Darwin had supplied in the finest sense of the word. "It was an immeasurable advance," he declared, "which living Nature made when the first man developed from an animal, whether that was an ape or other creature, which was the racial ancestor of the ape as well. However, the actual proof of the descent of man from the ape has not yet been made. None of the known apes supplies the transitional stage." Still the theory of the descent of man was for him, "not only a logical, but also a moral postulate," whose value lies not in being a new dogma, but a light for further research.

His attitude came to light clearly in his famous controversy with Haeckel, in 1887, when the latter demanded that his monistic doctrine be introduced into the schools. Virchow objected strenuously to the teaching of the problems as though they were the conquests of science, taking the ground that this was contrary to the conscience of the natural scientist, who reckons only with facts. He likewise protested vigorously against any form of compulsion of conscience.

In approaching the problem of the origin of species, Virchow saw more hope of attaining a solution through physiology and pathology than through morphology, which gives only the possibility and not the proof of evolution. "He who teaches us," he wrote, "to develop a Schimmelpilz out of a Spaltpilz will have accomplished more than all the heralds of the geneological tree of man."

In his "Rassenbildung und Erblichkeit" (1896), he developed his doctrine of the pathological nature of variations from type. Originally each species, or variation from type, is produced by a permanent disturbance of the parental organism, and is in this sense pathological. Only by inheritance in the descendants does this condition become physiological: but, up to now, it is completely unknown why one disturbance is inherited, another not. Races, too, are only hereditary species, which rest upon a pathological disturbance in the parental organism. Probably in most cases the disturbance is produced by the environment, but often also by causes contained within the organism, which become effective only after birth.

Virchow's general interest in historical questions and his special anthropological studies led him into the field of prehistoric archeology. To this study, in Germany, he did a great service by raising it from dilettantism to a recognized position among the social sciences. He was early attracted by the history of his birthplace, Schivelbein, and, in 1866, wrote on its antiquities. From 1867 onwards, he became a regular participant in the international congresses for prehistoric archeology and anthropology. In 1869, he began his investigations of North German pile dwellings. A careful study of ceramics enabled him to determine that these pile dwellings were of later origin than the corresponding structures in South Germany, and, on the basis of similar evidence, he showed that the so-called Wendish cemeteries were really pre-Slavic in origin.

Becoming interested in the question of the mutual influences of prehistoric cultures, Virchow made an exhaustive study of the ancient amber and flint traffic routes in Central Europe. It was largely as a result of a friendship formed in 1875 with the Homeric enthusiast Schliemann that Virchow extended his archeological studies beyond the limits of his native country. In 1879 he accompanied Schliemann to the site of ancient Troy, in 1881 to the Caucasus, and in 1888 to Egypt, Nubia and the Peloponnesus. It was Virchow's influence that induced Schliemann to entrust his later excavations at Troy to the experienced archeologist Dörpfeld.

Virchow's expedition to the Caucasus was undertaken in the hope of finding there the source of the European bronze age culture, but in his report on the Graveyard of Koban (1883) he decided against the possibility of this theory. One important result of his work in Egypt was that he was the first to adduce positive evidence for a period of neolithic culture in the Nile Valley.

His Caucasian studies led Virchow to encourage others to interest themselves in the origins of the civilization of the Near East, and through the work of his pupils the civilization of the ancient kingdom of Colchis was revealed. Shortly before his death, Virchow had assumed the honorary direction of a new German Society for the Investigation of Asia Minor, especially Anatolia and Cappadocia.

In these closely related fields of anthropology, ethnology and prehistoric archeology, Virchow's fame rests not so much upon the infallibility of his own conclusions as upon his introduction of scientific methods of investigation, his establishment of organizations for cooperative effort in research, his logical and independent thinking and his deep sense of truth. A great worker himself, he stimulated the work of others, not only in his own country, but also abroad, and so became, in the best sense of the word, an international figure.

THE BIOLOGY OF DEATH—V. THE INHERITANCE OF DURATION OF LIFE IN MAN[1]

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1. The Determination of Longevity

IN the series of papers up to this point we have seen, in the first place, that immortality is a potential attribute of cells generally and becomes actually realized when conditions are so arranged as to make continued life possible. These conditions are not realized in the metazoan body because of differentiation and specialization of structure and function. What actually happens in the metazoa is that sooner or later some differentiated organ or system of organs gets to functioning badly and upsets the delicate balance of the whole. As a result the entire organism presently dies. We have further seen that in the case of man, where alone quantitative data are available, the breakdown of particular organ systems, and consequent death of the whole, occurs in a highly orderly manner in respect of time or age. Each organ system has a characteristic time curve for its breakdown, differing from the curve of any other system. The problem which now confronts us is to find out what lies back of these characteristic time curves and determines their form. In view of the biological facts about death which we have learned, what determines that John Smith shall die at 58, while Henry Jones lives to the obviously more respectable age of 85? We have seen that there is every reason to believe that all the essential cells of both their bodies are inherently capable under proper conditions of living indefinitely. We are further agreed that it is the differentiated and specialized structure of their bodies which prevents the realization of these favorable conditions. But all this helps us not at all to understand why in fact one lives nearly 30 years longer than the other.

It may help to visualize this problem of the determination of longevity to consider an illustrative analogy. Men behave in respect of their duration of life not unlike a lot of eight-day clocks cared for by an unsystematic person, who does not wind them all to an equal degree and is not careful about guarding them from accident. Some he winds up fully, and they run their full eight days. Others he winds only half way and they stop after four days. Again the clock which

[1]Papers from the Department of Biometry and Vital Statistics. School of Hygiene and Public Health, Johns Hopkins University, No. 32.

has been wound up for the full eight days may fall off the shelf and be brought to a stop at the third day. Or someone may throw some sand in the works when the caretaker is off his guard. So, similarly, some men behave as though they had been wound up for a full 90-year run, while others are but partially wound up and stop at 40 or 65, or some other point. Or, again, the man wound up for 80 years may, like the clock, be brought up much short of that by an accidental invasion of microbes, playing the rôle of the sand in the works of the clock. It is of no avail for either the clock or the man to say that the elements of the mechanism are in whole or in major part capable of further service. The essential problem is: what determines the goodness of the original winding? And what relative part do external things play in bringing the running to an end before the time which the original winding was good for? It is with this problem of the winding up and running of the human mechanism that the present paper will deal.

There are two general classes of factors which may be involved here. These are, on the one hand, heredity and, on the other hand, environment, using the latter term in the broadest sense. Inasmuch as we can be reasonably sure on *a priori* grounds that longevity, like most other biological phenomena, is influenced by both heredity and environment, the problem practically reduces itself to the measuring of the relative importance of each of these two factor groups in determining the results we see. But before we start the discussion of exact measurements in this field, let us first examine some of the general evidence that heredity plays any part at all in the determination of longevity.

2. The Hyde Family

The first material which we shall discuss is that provided by the distinguished eugenist, Dr. Alexander Graham Bell, in his study of the Hyde family. Every genealogist is familiar with the "Genealogy of the Hyde Family," by Reuben H. Walworth. It is one of the finest examples in existence of careful and painstaking genealogical research. Upon the data included in this book, Bell has made a most interesting and penetrating analysis of the factors influencing longevity. At first thought one might conclude that highly biased results would probably flow from the consideration of only one family. Bell meets this point very well, however, in the following words:

> A little consideration will show that the descendants did not constitute a single family at all, and indeed had very little of the Hyde blood in them.
>
> Even the children of William Hyde owed only half of their blood to him, and one-half to his wife. The grandchildren owed only one-quarter of their blood to William Hyde, and three quarters to other people, etc. The descendants of the seventh generation, and there are hundreds of them, owed only one sixty-fourth of their blood to William Hyde, and sixty-three sixty-fourths to the new blood introduced through successive generations of marriages with persons not of the Hyde blood at all.

It will thus be seen that the thousands of descendants noted in the Hyde Genealogy constitute rather a sample of the general population of the country than a sample of a particular family in which family traits might be expected to make their appearance.

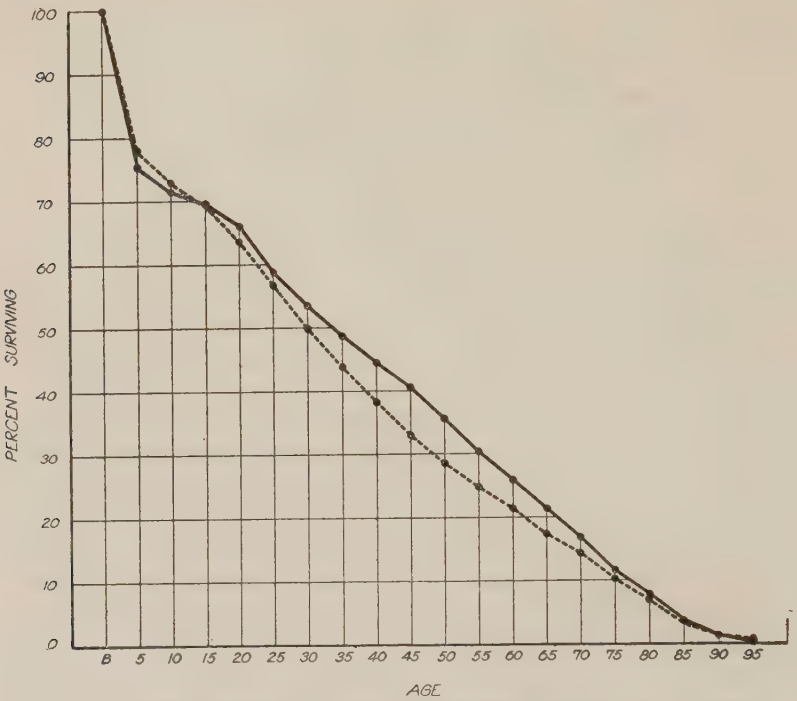

FIG. 1. SHOWING SURVIVAL CURVES OF MEMBERS OF THE HYDE FAMILY (Plotted from Bell's data)

The substantial normality of the material is shown in Figure 1, which gives the l_x line, that is, the number of survivors at each age, of the 1,606 males and 1,352 females for whom data were available. The solid line is the male l_x line and the dotted line the female l_x. It is at once apparent that the curves have the same general sweep in their passage over the span of life as has the general population life curve discussed in the preceding paper. The descent is a little steeper in early adult life. The female curve differs in two respects from the normal general population curves. In the first place, beginning at age 15 and continuing to age 90, the female curve lies below that for the males, whereas normally for the general population it lies above it. This denotes a shorter average duration of life in the females than in the males, the actual figures being 35.8 years for the males and 33.4 years for the females. Bell attributes the difference to the strain of child-bearing by the females in this rather highly fertile group of people, belonging in the main to a period when restrictions upon size of family were less common and less extensive than now. In the second place, the female l_x curve is actually convex to the base through-

out a considerable portion of middle life whereas normally this portion of the curve presents a concave face to the base.

Apart from these deviations, which are of no particular significance for the use which Bell makes of the data, the Hyde material is essentially normal and similar to what one would expect to find in a random sample of the general population. In this material there were 2,287 cases in which the ages at death of the persons and the ages at death of their fathers were known. It occurred to Bell to arrange this material in such a way as to show what, if any, relation existed between age at death of the parent and that of the offspring. He arranged the parents into four groups, according to the age at which they died, and the offspring into five groups upon the same basis. In the case of the parents the groups were: First, those dying under 40;

TABLE I

Analysis of the Hyde family data by person's age at death, showing the number and percentage having (a) fathers and (b) mothers who died at the age periods named. (From Bell).

Person's age at death	Father's age at death				
	Stated	-40	40-60	60-80	80+
Stated	2,287	66	522	1,056	643
Under 20	669	20	189	299	161
20 and under 40	538	18	140	269	111
40 and under 60	467	12	116	215	124
60 and under 80	428	13	57	196	162
80 and over	185	3	20	77	85
Percentages					
Stated	100.0	2.9	22.8	46.2	28.1
Under 20	100.0	3.0	28.2	44.7	24.1
20 and under 40	100.0	3.4	26.0	50.0	20.6
40 and under 60	100.0	2.6	24.8	46.0	26.6
60 and under 80	100.0	3.0	13.3	45.8	37.5
80 and over	100.0	1.6	10.8	41.6	46.0

Person's age at death	Mother's age at death				
	Stated	-40	40-60	60-80	80+
Stated	1,805	191	435	713	466
Under 20	511	88	129	199	95
20 and under 40	407	42	104	176	85
40 and under 60	379	27	92	159	101
60 and under 80	360	26	80	129	125
80 and over	148	8	30	50	60
Percentages					
Stated	100.0	10.6	24.1	39.5	25.8
Under 20	100.0	17.2	25.2	39.0	18.6
20 and under 40	100.0	10.3	25.6	43.2	20.9
40 and under 60	100.0	7.1	24.3	42.0	26.6
60 and under 80	100.0	7.2	22.2	35.9	34.7
80 and over	100.0	5.4	20.3	33.8	40.5

second, between 40 and 60; third, between 60 and 80; and fourth, at age 80 and over. The groups for the offspring were the same, except that the first was divided into two parts, namely, those dying under 20 and those dying between 20 and 40. The resulting figures are exhibited in Table 1.

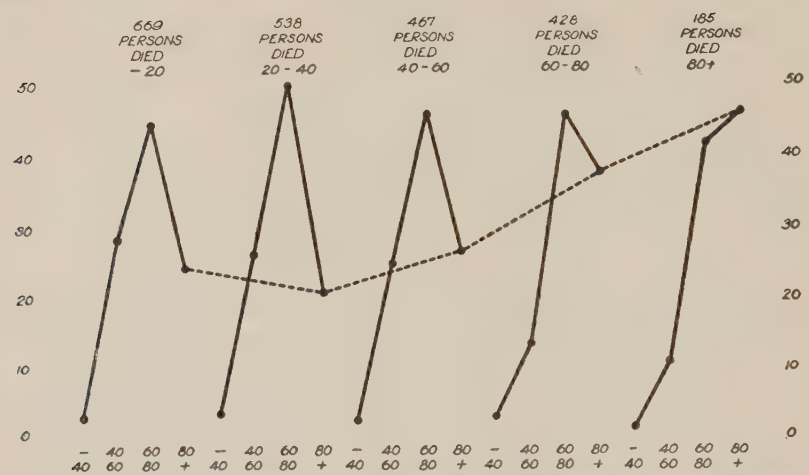

FIG. 2. INFLUENCE OF FATHER'S AGE AT DEATH UPON LONGEVITY OF OFFSPRING. First dot in each diagram shows the percentage having fathers who died at 40; second dot the percentage having fathers who died from 40—60; third dot the percentage having fathers who died from 60—80; fourth dot the percentage having fathers who died 80+

The results for father and offspring are shown in Figure 2, based upon the data of Table 1. In each of the 5 polygons, one for each offspring group, the first dot shows the percentage of fathers dying under 40; the second dot the percentage of fathers dying between 40 and 60; and so on, the last dot in each curve showing the percentage of fathers dying at age 80 and over. It is to these last dots that attention should be particularly directed. It will be noted that the dotted line connecting the last dots of each of the 5 polygons in general rises as we pass from the left-hand side of the diagram to the right-hand side. In the case of offspring dying under 20, 24 per cent. of their fathers died at ages over 80. About 21 per cent. of the fathers of offspring dying between 20 and 40 lived to be 80 years or over. For the next longer-lived group of offspring, dying between 40 and 60, the percentage of fathers living to 80 or over rose to 27 per cent. In the next higher group, the percentage is nearly 38, and finally the extremely long-lived group of offspring, the 185 persons who died at ages of 80 and over, had 46 per cent. or nearly one half of their fathers living to the same great age. In other words, we see in general that the longer-lived a group of offspring is, on the average, the longer-lived are their fathers, on the average; or, put in another way, the higher the percentage of very long-lived fathers which this group will have as compared with shorter-lived individuals.

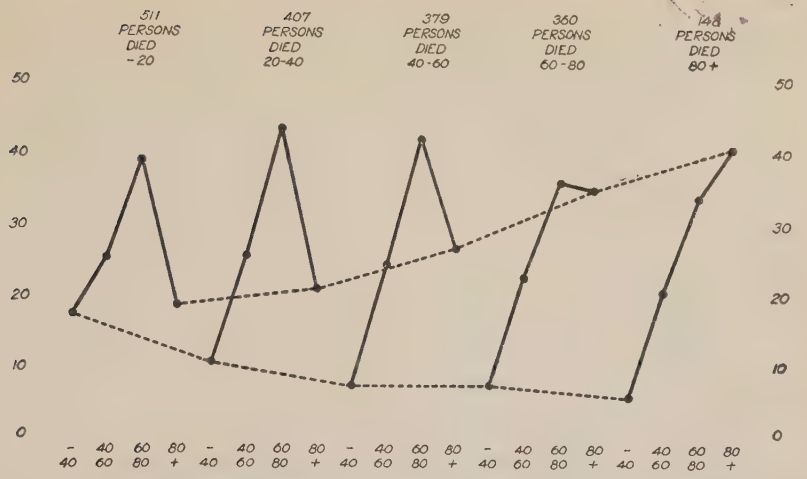

FIG. 3. INFLUENCE OF MOTHER'S AGE AT DEATH UPON LONGEVITY OF OFFSPRING. First dot in each diagrom shows the percentage having mothers who died at 40; second dot the percentage having mothers who died at 40—60; third dot the percentage having mothers who died 60—80; fourth dot the percentage having mothers who died 80+

Figure 3 shows the same sort of data for mothers and offspring. Here we see the curve of great longevity of parents rising in an even more marked manner than was the case with fathers of offspring. The group of offspring dying at ages under 20 had only 19 per cent. of their mothers living to 80 and over, whereas the group of offspring who lived to 80 and beyond had 41 per cent. of their mothers attaining the same great age. At the same time we note from the dotted line at the bottom of the chart that as the average age at death of the offspring increases, the percentage of mothers dying at early ages, namely, under 40, as given by the first dots, steadily *decreases* from 17 per cent. at the first group to just over 5 per cent. for the offspring dying at very advanced ages.

These striking results demonstrate at once that there is a definite and close connection between the average longevity of parents and that of their children. Extremely long-lived children have a much higher percentage of extremely long-lived parents than do shorter lived children. While the diagrams demonstrate the fact of this connection, they do not measure its intensity with as great precision as can be obtained by other methods of dealing with the data. A little farther on we shall take up the consideration of this more precise method of measurement of the hereditary influence in respect of longevity.

In the preceding diagrams we have considered each parent separately in connection with the offspring in regard to longevity. We shall, of course, get precisely the same kind of result if we consider both parents together. For the sake of simplicity, taking only the

cases of extreme longevity, namely, persons living to 80 or over—the essential data are given in Table 2.

TABLE 2

Longevity of parents of persons dying at 80 and over. (From Bell).

Age at death of parents	Number of persons	Number of persons lived 80+	Per cent. of persons lived 80+
Stated	1,594	139	8.7
Lived to be 80+			
Neither parent.....	827	44	5.3
One parent (not other)...	583	57	9.8
Both parents.....	184	38	20.6
Father (not mother).....	337	38	11.3
Mother (not father).....	246	19	7.7

From this table it is seen that where neither parent lived to be 80, only 5.3 per cent. of the offspring lived to be 80 or over, the percentage being based upon 827 cases. Where one parent, but not the other, lived to be 80 or older, 9.8 per cent. of the offspring lived to be 80 or older, the percentage here being based upon 583 cases. Where both parents lived to be 80 or older 20.6 of the persons lived to the same great age, the percentage being based upon 184 cases. Thus it appears that in this group of people four times as many attained great longevity if both of their parents lived to an advanced age, as attained this age when neither parent exhibited great longevity. The figures from the Hyde family seem further to indicate that the tendency of longevity is inherited more strongly through the father than through the mother. Where the father, but not the mother, lived to be 80 or older, 11.3 per cent. of the persons lived to age 80 or more, there being 337 cases of this kind. Where the mother, but not the father, lived to be 80 or older, only 7.7 per cent., or nearly 4 per cent. fewer of the persons lived to the advanced age of 80 or more, there being 246 cases of this sort. Too much stress is not, however, to be laid upon this parental difference because the samples after all are quite small.

One other point in this table deserves consideration. Out of the 1,594 cases as a whole, less than 9 per cent. of the persons lived to the advanced age of 80 or more. But out of this number there are 767, or 48.1 per cent., nearly one-half of the whole, who had parents who lived to 80 or more years.

Another interesting and significant way in which one may see the great influence of the age of the parents at death upon the longevity of the offspring, is indicated in Table 3, where we have the average duration of life of individuals whose fathers and mothers died at the specified ages.

TABLE 3

Showing the influence of a considerable degree of longevity in both father and mother upon the expectation of life of the offspring. (After Bell). (In each cell of the table the open figure is the average duration of life of the offspring and the bracketed figure is the number of cases upon which the average is based).

Father's age at death	Mother's age at death		
	Under 60	60-80	Over 80
Under 60	32.8 years (128)	33.4 years (120)	36.3 years (74)
60-80	35.8 (251)	38.0 (328)	45.0 (172)
Over 80	42.3 (131)	45.5 (206)	52.7 (184)

We see that the longest average duration of life, or expectation of life, was of that group which had both mothers and fathers living to age 80 and over. The average duration of life of these persons was 52.7 years. Contrast this with the average duration of life of those whose parents both died under 60 years of age, where the figure is 32.8 years. In other words, it added almost exactly 20 years to the average life of the first group of people to have extremely long-lived parents, instead of parents dying under age 60. In each column of the table the average duration of life advances as we proceed from top to bottom—that is, as the father's age at death increases—and in each row of the table the average expectation of life of the offspring increases as we pass from left to right—that is, with increasing age of the mother at death. However the matter is taken, a careful selection of one's parents in respect of longevity is the most reliable form of personal life insurance.

So much for Bell's analysis of longevity in the Hyde family. We have seen that it demonstrates with the utmost clearness and certainty that there is an hereditary influence between parent and offspring affecting the expectation of longevity of the latter. Bell's method of handling the material does not provide any precise measure of the intensity of this hereditary influence, nor does it furnish any indication of its strength in any but the direct line of descent. Of course, if heredity is a factor in the determination of longevity we should expect its effects to be manifested as between brothers and sisters, or in the avuncular relationships, and in greater or less degree in all the other collateral and more remote direct degrees of kinship. Happily, we have a painstaking analysis, with a quantitative measure of the relative influence of heredity in the determination of longevity, which was carried out many years before Bell's work on the Hyde family, by the pioneer in this field, Prof. Karl Pearson. His demonstration of the inheritance of longevity appeared more than twenty years before that of Bell. I have called attention to the latter's work first merely be-

cause of the greater simplicity and directness of his demonstration. We may now turn to a consideration of Pearson's more detailed results.

3. Pearson's Work

The material used by Pearson and his student, Miss Beeton, who worked with him on the problem, came from a number of different sources. Their first study dealt with three series from which all deaths recorded as due to accident were excluded. The first series included one thousand cases of the ages of fathers and sons at death, the latter being over 22.5 years of age, taken from Foster's "Peerage." The second series consisted of a thousand pairs of fathers and sons, the latter dying beyond the age of 20, taken from Burke's "Landed Gentry." The third series consisted of ages at death of one thousand pairs of brothers dying beyond the age of 20 taken from the "Peerage." It will be noted that all these series considered in this first study dealt only with inheritance in the male line. The reason for this was simply that in such books of record as the "Peerage" and "Landed Gentry" sufficiently exact account is not given of the deaths of female relatives. In a second study the material was taken from the pedigree records of members of the English Society of Friends, and from the Friends Provident Association. This material included data on inheritance of longevity in the female line and also provided data for deaths of infants, which were lacking in the earlier used material. The investigation was grounded upon that important branch of modern statistical calculus known as the method of correlation. For each pair of relatives between whom it was desired to study the intensity of inheritance of longevity a table of double entry was formed, like the one shown here as Table 4.

TABLE 4

Correlation table showing the correlation between father and son in respect of duration of life.

Duration of Life of Son	Duration of Life of Father																	
	23	28	33	38	43	48	53	58	63	68	73	78	83	88	93	98	103	Totals
23	1	1	2	5	3	11	6	7	11	9	6	12	8	2		2		86
28				1	6	4	5	12	15	10	13	10	7		1	1		85
33			1	2	2	5	7	8	7	10	7	8	8	4	1			70
38		1	1	2		2	8	5	3	9	11	11	9	5	2	1		70
43		1			1	5	1	5	6	11	10	10	17	5				72
48			1	1	2	5	5	4	6	9	12	15	5	3				68
53		1		3		5	7	3	2	11	11	14	10	1	1	1		70
58			1	3		4	5	10	8	10	5	8	9	3		2		68
63		2	1	3	5	1	4	8	13	9	11	11	11	5				84
68			1	6	3	6	7	5	5	6	14	16	12	7	2			90
73		1		2	1	6	5	4	7	9	10	14	13	8	8	1	1	90
78			1	1	2	2	4	4	4	10	5	8	9	4		3		57
83				1	1	5	3	1	2	3	7	10	13	3	2	2		53
88		1				2	3		1	4	7	5	1	2		2		28
93						1				2	2							5
98						1						1		1	1			4
Totals	1	8	9	30	26	65	70	76	90	122	131	153	132	53	18	15	1	1000

The figures in each cell or compartment of this table denote the frequency of occurrence of pairs of fathers and adult sons having respectively the durations of life indicated by the figures in the margins. Thus we see, examining the first line of the table, that there were 11 cases in which the average duration of life of the father was 48 years and that of the adult son 23 years. Farther down and to the right in the table there were 13 cases in which the average duration of life of the father and the son was in each case 83 years. These cases are mentioned merely as illustrations. The whole table is to be read in the same manner.

From such a table as this it is possible to calculate, by well-known mathematical methods, a single numerical constant of somewhat unique properties known as the coefficient of correlation, which measures the degree of association or mutual dependence of the two variables included in such double entry tables. This coefficient measures the amount of resemblance or association between characteristics of individuals or things. It is stated in the form of a decimal which may take any value between 0 and 1. As the correlation coefficient rises to 1 we approach a condition of absolute dependence of the variables one upon the other. As it falls to zero we approach a condition of absolute independence, where the one variable has no relation to the other in the amount or direction of its variation. The significance of a correlation coefficient is always to be judged, in any particular case, by the magnitude of a constant associated with it called the probable error. A correlation coefficient may be regarded as certainly significant when it has a value of 4 or more times that of its probable error, which is always stated after the coefficient with a combined plus and minus sign between the two. The coefficient is probably significant when it has a value of not less than 3 times its probable error. By "significant" in this connection is meant that the coefficient expresses true organic relationship and not merely a random chance result.

In Table 5 are the numerical results from the first study based upon the "Peerage" and "Landed Gentry."

TABLE 5

Inheritance of duration of life in male line. Data from "Peerage" and "Landed Gentry." (Beeton and Pearson).

Relatives		Correlation coefficient	Ratio of coefficient to its probable error.
x	y	r_{xy}	$r_{xy} \div E_r$
Father ("Peerage")	Son, 25 years and over	.115 ± .021	5.5
Father ("Landed Gentry")	Son, 20 years and over	.142 ± .021	6.8
Father ("Peerage")	Son, 52.5 years and over	.116 ± .023	5.0
Father ("Landed Gentry")	Son, 50 years and over	.113 ± .024	4.7
Brother (Peerage")	Brother	.260 ± .020	13.0

It is seen at once that all of the coefficients are significant in comparison with their probable errors. The last column of the table gives

the ratio of the coefficient to its probable error, and in the worst case the coefficient is 4.7 times its probable error. The odds against such a correlation having arisen from chance alone are about 655 to 1. Odds such as these may be certainly taken as demonstrating that the results represent true organic relationship and not mere chance. All of the other coefficients are certainly significant, having regard to their probable errors. Furthermore, they are all positive in sign, which implies that a variation in the direction of increased duration of life in one relative of the pair is associated with an increase in expectation of life in the other. It will be noted that the magnitude of the correlation between brother and brother is about twice as great as in the case of correlation of father with son. From this it is provisionally concluded that the intensity of the hereditary influence in respect of duration of life is greater in the fraternal relationship than in the parental. It evidently makes no difference, broadly speaking, so far as these two sets of material are concerned, whether there are included in the correlation table all adult sons, whatever their age, or only adult sons over 50 years of age. The coefficients in both cases are essentially of the same order of magnitude.

Perhaps some one will be inclined to believe that the correlation between father and son, and brother and brother, in respect of the duration of life arises as a result of similarity of the environments to which they are exposed. Pearson's comments on this point are penetrating, and I believe absolutely sound. He says:

> There may be some readers who will be inclined to consider that much of the correlation of duration of life between brothers is due to there being a likeness of their environment, and that thus each pair of brethren is linked together and differentiated from the general population. But it is difficult to believe that this really affects *adult* brothers or a father and his adult offspring. A man who dies between 40 and 80 can hardly be said to have an environment more like that of his brother or father, who died also at some such age, than like any other member of the general population. Of course, two brothers have usually a like environment in infancy, and their ages at death, even if they die adults, may be influenced by their rearing. But if this be true, we ought to find a high correlation in ages at death of brethren who die as minors. As a matter of fact this correlation for minor and minor is 40 to 50 per cent. less than in the case of adult and adult. It would thus seem that identity of environment is not the principal factor in the correlation between ages of death, for this correlation is far less in youth than in old age.

The results regarding minors to which Pearson refers are shown in Table 6. This table gives the results of the second study made by Beeton and Pearson on inheritance of duration of life, based upon the records of the Friends Societies. It appears in the upper half of the table that wherever a parent, father or mother, appears with a minor son or daughter the correlation coefficients are small in magnitude. In some cases they are just barely significant in comparison with their probable errors, as for example, the correlation of father and minor

TABLE 6

Inheritance of duration of life. Data from Quaker records. (Beeton and Pearson).

Relatives		Correlation coefficient	Ratio of coefficient to its probable error.
x	y	r_{xy}	$r_{xy} \div E_r$
Father	Adult son	0.135 ± .021	6.4
Father	Minor son	.087 ± .022	4.0
Father	Adult daughter	.130 ± .020	6.5
Father	Minor daughter	.052 ± .023	2.3
Mother	Adult son	.131 ± .019	6.9
Mother	Minor son	.076 ± .024	3.2
Mother	Adult daughter	.149 ± .020	7.5
Mother	Minor daughter	.138 ± .024	5.7
Elder adult brother	Younger adult brother	.229 ± .019	12.1
Adult brother	Adult brother	.285 ± .020	14.3
Minor brother	Minor brother	.103 ± .029	3.6
Adult brother	Minor brother	−.026 ± .025	1.0
Elder adult sister	Younger adult sister	.346 ± .018	19.2
Adult sister	Adult sister	.332 ± .019	17.5
Minor sister	Minor sister	.175 ± .031	5.6
Adult sister	Minor sister	−.026 ± .029	.9
Adult brother	Adult sister	.232 ± .015	15.5
Minor brother	Minor sister	.144 ± .025	5.8
Adult brother	Minor sister	−.006 ± .035	.2
Adult sister	Minor brother	−.027 ± .024	1.1

The cases above the horizontal line are all direct lineal inheritance; those below the line collateral inheritance.

son, and that of mother and minor daughter. In the other cases involving minors the coefficients are so small as to be insignificant. On the other hand, in every case of correlation between parent and *adult* offspring of either sex, the coefficient is 6 or more times its probable error, and must certainly be regarded as significant. It will further be noted that the magnitude of the coefficients obtained from these Quaker records is of the same general order as was seen in the previous table based on the "Peerage" and "Landed Gentry" material.

The lower part of the table gives the results for various fraternal relationships. In general the fraternal correlations are higher than the parental. The coefficients for minors or for minors with adults are very low and in most cases not significantly different from zero.. In four cases—namely, adult brother with minor brother; adult sister with minor sister; adult brother with minor sister; and adult sister with minor brother—the coefficients are all negative in sign, although in no one of the cases is the coefficient significant in comparison with its probable error. A minus sign before a correlation coefficient means that an increase in the value of one of the variables is associated with a decrease in the value of the other. So that these negative cofficients would mean, if they were significant, that the greater the age at death of an adult brother, the lower the age at death of his minor brother

or sister. But the coefficients are actually sensibly equal to zero. Pearson points out that the minus sign in the case of these correlations of adult with minor exhibits the effect of the inheritance of the mortality of youth. Minors dying from 16 to 20 are associated with adults dying from 21 to 25. That is, minors dying late correspond to adults dying early. This situation may be a peculiarity of the Quaker material with which this work deals. There is urgent need for further study of the inheritance of the duration of life on more and better material than any which has hitherto been used for the purpose. I have under way in my own laboratory at the present time an extensive investigation of this kind, in which there will be hundreds of thousands of pairs of relatives in the individual correlation tables instead of thousands, and all types of collateral kinship will be represented. Because of the magnitude of the investigation, however, it will be still a number of years before the results will be in hand for discussion.

The facts which have been presented leave no doubt as to the reality of the inheritance factor as a prime determinant of the length of the life span.

At the beginning it was pointed out that it was on *a priori* grounds highly probable that duration of life is influenced by both heredity and environment, and that the real problem is to measure the comparative effect of these two general sets of factors. We have seen that the intensity of inheritance of duration of life, taking averages, is of the order indicated by the following coefficients.

Parental correlation (adult children) $r=.1365$
Fraternal correlation (adults) $r=.2831$

Now we have to ask this question: What are the values of parental and fraternal correlation for characters but slightly if at all affected in their values by the environment? Happily, Pearson has provided such values in his extensive investigations on the inheritance of physical characters in man.

TABLE 7
Parental inheritance of physical characters in man. (*Pearson*).

Pair	Organ	Correlation
Father and Son	Stature	.51
" " "	Span	.45
" " "	Forearm	.42
" " "	Eye Color	.55
Father and Daughter	Stature	.51
" " "	Span	.45
" " "	Forearm	.42
" " "	Eye Color	.44
Mother and Son	Stature	.49
" " "	Span	.46
" " "	Forearm	.41
" " "	Eye Color	.48
Mother and Daughter	Stature	.51
" " "	Span	.45
" " "	Forearm	.42
" " "	Eye Color	.51

In Table 7 are given the values of the parental correlations for the four physical characters—stature, span, forearm length, and eye color. Now it is obvious that the differences of environmental forces impinging upon the various members of a homogeneous group of middle class English families (from which source the data for these correlations were drawn) can by no possibility be great enough to affect sensibly the stature, the arm-length, or the eye color of the adults of such families. It would be preposterous to assert that the resemblance between parents and offspring in respect of eye color is due solely, or even sensibly, to similarity of environment.

It is due to heredity and substantially nothing else. Now the average value of the 16 parental coefficients for the inheritance of physical characters shown in the table is

$$r=.4675$$

TABLE 8

Fraternal inheritance of physical characters in man. (*Pearson*).

Pair	Organ	Correlation
Brother and Brother	Stature	.51
" " "	Span	.55
" " "	Forearm	.49
" " "	Eye color	.52
" " "	Cephalic index	.49
" " "	Hair color	.59
Sister and Sister	Stature	.54
" " "	Span	.56
" " "	Forearm	.51
" " "	Eye color	.45
" " "	Cephalic index	.54
" " "	Hair color	.56
Brother and Sister	Stature	.55
" " "	Span	.53
" " "	Forearm	.44
" " "	Eye color	.46
" " "	Cephalic index	.43
" " "	Hair color	.56

Table 8 shows the coefficients for the fraternal inheritance of six physical characters, cephalic index (the ratio of head length and head breadth) and hair colour having been added to those given in the parental table. Again it is seen that the coefficients have all about the same values, and it is as apparent as before that the resemblance between brother and sister, for example, in eye-color, or arm length, or shape of head can not for a moment, because of the nature of the characters themselves, be supposed to have arisen because of the similarity of environment. The average value of all these fraternal coefficients is

$$r = .5156$$

From these data, with the help of a method due to Pearson, it is possible to determine the percentage of the death rate dependent upon the inherited constitution, and the percentage not so dependent. If

pN be the number of deaths in N cases which depend in no way upon the inherited constitution of the individual, then $(1\text{-}p)$ will represent the chance of an individual dying because of his inherited constitutional makeup, and $(1\text{-}p)^2$ will be the chance of a pair of individuals, say two brothers, both dying from causes determined by inheritance. If further r denotes the observed correlation between individuals in respect of duration of life, and r_o the correlation between the same kin in respect of such measured physical characters as those just discussed, in the determination of which it is agreed that environment can play only a small part, we have the following relation:

$$\frac{r}{r_o} = (1\text{-}p)^2$$

Substituting the ascertained values we have

1. From parental correlations.

$$0.1365 = .4675\ (1\text{-}p)^2$$
$$(1\text{-}p)^2 = .292$$
$$(1\text{-}p) = .54$$

2. From fraternal correlations

$$0.2831 = .5156\ (1\text{-}p)^2$$
$$(1\text{-}p) = .74$$

From these figures it may be concluded, and Pearson does so conclude, that from 50 to 75 per cent. of the general death rate within the group of the population on which the calculations are based, is determined fundamentally by factors of heredity and is not capable of essential modification or ameloriation by any sort of environmental action, however well intentioned, however costly, or however well advertised. *Mutatis mutandis* the same conclusion applies to the duration of life. I have preferred to state the conclusion in terms of death rates because of the bearing it has upon a great deal of the public health propaganda so loosely flung about. It need only be remembered that there is a perfectly definite functional relation between death rate and average duration of life in an approximately stable population group, expressible by an equation, in order to see that any conclusion as to the relative influence of heredity and environment upon the general death rate must apply with equal force to the duration of life.

4. The Selective Death Rate in Man

If the duration of life were inherited it would logically be expected that some portion of the death rate must be selective in character. For inheritance of duration of life can only mean that when a person dies is in part determined by that individual's biological constitution or makeup. And equally it is obvious that individuals of weak and unsound constitution must, on the average, die earlier than those of strong, sound, and vigorous constitution. Whence it follows that the chances of leaving offspring will be greater for those of sound constitution

than for the weaklings. The mathematical discussion which has just been given indicates that from one-half to three-fourths of the death rate is selective in character, because that proportion is determined by hereditary factors. Just in proportion as heredity determines the death rate, so is the death rate selective. The reality of the fact of a selective death rate in man can be very easily shown graphically.

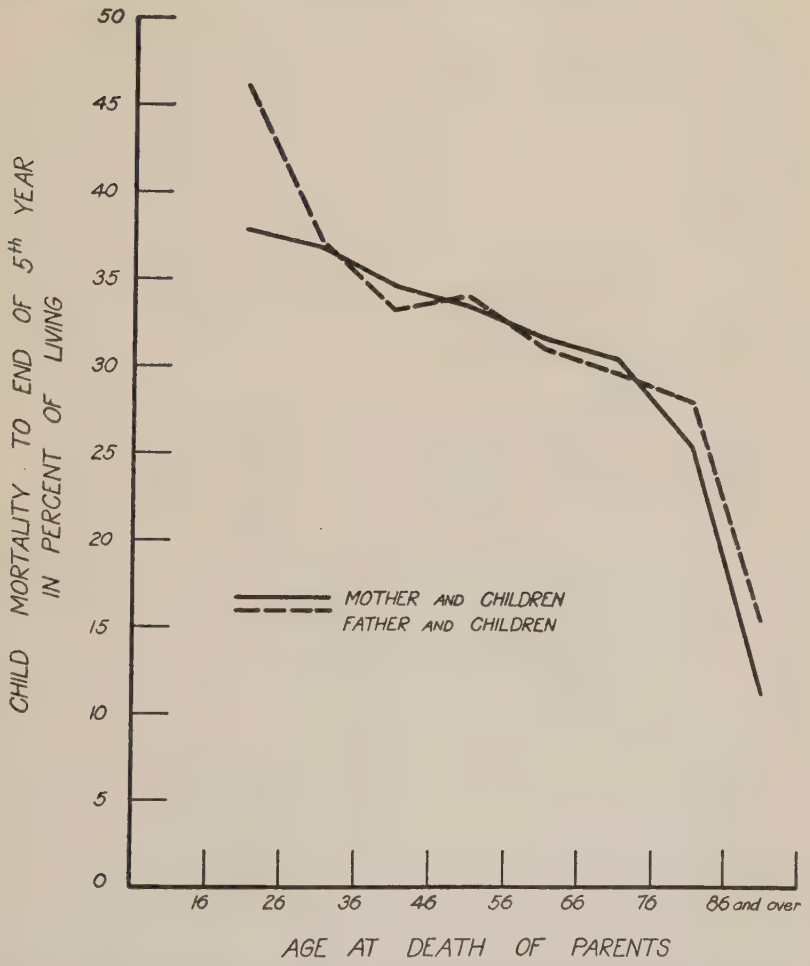

FIG. 4. DIAGRAM SHOWING THE INFLUENCE OF AGE AT DEATH, PARENTS UPON THE PERCENTAGE OF OFFSPRING DYING UNDER 5 YEARS. (After Ploetz)

In Fig. 4 are seen the graphs of some data from European royal families, where no neglect of children, degrading environmental conditions, or economic want can have influenced the results. These data were compiled by the well-known German eugenist, the late Professor Ploetz of Munich. The lines show the falling percentage of the infantile death rate as the duration of life of the father and mother in-

creases. Among the children of short-lived fathers and mothers, at the left end of each line, is found the highest infant mortality, while among the offspring of long-lived parents the lowest infant mortality occurs, as shown at the righthand end of the diagram.

The results so far presented regarding a selective death rate and inheritance of duration of life, have come from selected classes; the aristocracy, royalty or Quakers. None of these classes can be fairly said to represent the general population. Can the conclusion be transferred safely from the classes to the masses? To the determination of this point one of Pearson's students, Dr. E. C. Snow, addressed himself. The method which he used was, from the necessities of the case, a much more complicated and indirect one than that of Pearson and Ploetz. Its essential idea was to see whether infant deaths weeded out the unfit and left as survivors the stronger and more resistant. All the infants born in a single year were taken as a cohort and the deaths occurring in this cohort in successive years were followed through. Resort was had to the method of partial or net correlation. The variables correlated in the case of the Prussian data were these:

1. x_0 = Births in year a given cohort started.
2. x_1 = Deaths in the first two years of life.
3. x_2 = Deaths in the next eight years of life.
4. x_3 = Deaths in the ten years of all individuals not included in the particular cohort whose deaths are being followed.

In the case of the English data the variables were:

x_0 = Births in specified year.
x_1 = Deaths in the first three years of life of those born in specified year.
x_2 = Deaths in fourth and fifth years of life of those born in specified year.
x_3 = The "remaining" deaths under 5.

The underlying idea was to get the partial or net correlation between x_1 and x_2, while x_0 and x_3 are held constant. If the mortality of infancy is selective, its amount should be negatively correlated to a significant degree with the mortality of the next eight years when the births in each district considered are made constant and when the general health environment is made constant. Under the constant conditions specified a negative correlation denotes that the heavier the infantile death rate in a cohort of births the lighter will be the death rate of later years, and *vice versa*. The last variable, x_3, is the one chosen, after careful consideration and many trials, to measure variation in the health environment. If any year is a particularly unhealthy one—an epidemic year for example—then this unhealthiness should be accurately reflected in the deaths of those members of the population not included in the cohort under review.

Snow's results for English and Prussian rural districts are set forth

TABLE 9

Snow's results on selective death rate in man. English and Prussian rural districts.

Data		Actual correlation $r_{12 \cdot 03}$	Expected correlation if no selection
Males:			
English Rural Districts	(1870)	−0.4483	−0.0828
	(1871)	− .3574	− .1014
	(1872)	− .2271	− .0807
Prussian Rural Districts	(1881)	− .9278	− .0958
	(1882)	− .6050	− .0765
Females:			
English Rural Districts	(1870)	− .4666	− .0708
	(1871)	− .2857	− .0505
	(1872)	− .5089	− .0496
Prussian Rural Districts	(1881)	− .8483	− .0933
	(1882)	− .6078	− .0705

in Table 9. From this table it is seen that in every case the correlations are *negative*, and therefore indicate that the mortality of early life is selective. Furthermore, the demonstration of this fact is completed by showing that the observed coefficients are from 3 to 10 times as great as they would be if there were no selective character to the death rate. The coefficients for the Prussian population, it will be noted, are of a distinctly higher order of magnitude than those for the English population. This divergence is probably due chiefly to differences in the quality of the fundamental statistical material in the two cases. The Prussian material is free from certain defects inherent in the English data, which cannot be entirely got rid of. The difference in the coefficients for the two successive Prussian cohorts represents, in Snow's opinion, probably a real fluctuation in the intensity of natural selection in the one group as compared with the other. How significant Snow's results are is shown graphically in Figure 5.

Snow's own comments on his results are significant. He says:

> The investigations of this memoir have been long and laborious, and the difficulties presented by the data have been great. Still, the general result cannot be questioned. *Natural selection, in the form of a selective death-rate, is strongly operative in man in the early years of life.* Those data which we believe to be the best among those we have used—the Prussian figures—show very high negative correlation between the deaths in the first two years of life and those in the next eight, when allowance is made for difference in environment. We assert with great confidence that a high mortality in infancy (the first two years of life) is followed by a corresponding low mortality in childhood, and conversely. The English figures do not allow such a comprehensive survey to be undertaken, but, so far as they go they point in the same direction as the Prussian ones. The migratory tendencies in urban districts militate against the detection of selective influences there, but we express the belief that those influences are just as prevalent in industrial

as in rural communities, and could be measured by other means if the data were forthcoming.

Our investigation substantiates for a general population the results found by Pearson and Ploetz for more restricted populations, and disagrees with many statements of health officers. It is with great reluctance that we point out this disagreement, and assert a doctrine which, in the present sentiment of society, is bound to be unpopular. We have no feelings of antagonism towards the efforts which have been made in recent years to save infant life, but we think that the probable consequences of such actions, so far as past experience can indicate them, should be completely understood. All attempts at the reduction of mortality of infancy and childhood should be made in the full knowledge of the facts of heredity. Everybody knows the extreme differences in constitutional fitness which exist in men and women. Few intelligent people can be ignorant of the fact that this constitutional fitness is inherited according to laws which are fairly definitely known. At the same time marriage is just as prevalent among those of weak stocks as

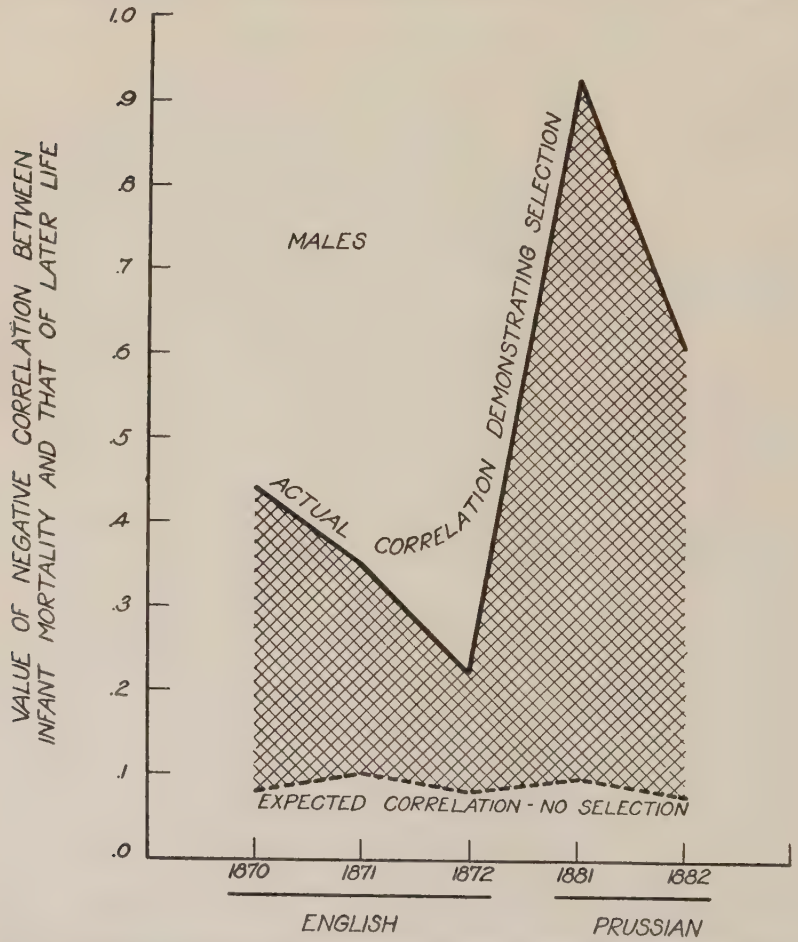

FIG. 5. SNOW'S RESULTS ON SELECTIVE DEATH RATE IN MAN. The cross-hatched area may be taken, in comparison with the small clear area at the bottom, to measure the influence of the selective death rate in increasing the correlations

among those of the vigorous, while the fertility of the former is certainly not less than that of the latter. Thus a proportion of the infants born every year must inevitably belong to the class referred to in the report as "weaklings," and, with Pearson's results before us, we are quite convinced that true infantile mortality (as distinct from the mortality due to accident, neglect, etc.—no small proportion of the whole) finds most victims from among this class. Incidentally we would here suggest that no investigation into the causes of infant and child mortality is complete until particulars are gathered by the medical officers of the constitutional tendencies and physical characters of the parents.

Our work has led us to the conclusion that infant mortality *does* effect a "weeding out" of the unfit; but, though we would give this conclusion all due emphasis, we do not wish to assert that any effort, however small, to the end of reducing this mortality is undesirable. Nobody would suggest that the difference between the infant rates in Oxfordshire and Glamorganshire (73 and 154 per 1,000 births respectively, in 1908) was wholly due to the constitutional superiority of the inhabitants of the former county. The "weeding-out" process is not uniform. In the mining districts of South Wales, accident, negligence, ignorance and unsanitary surroundings account for much. By causing improvements under these heads it may be possible to reduce the infant mortality of Glamorganshire by the survival of many who are not more unfit than are those who survive in Oxfordshire, and the social instincts of the community insist that this should be done.

This work of Snow's aroused great interest, and soon after its appearance was controverted, as it seems to me quite unsuccessfully, by Brownlee, Saleeby and others.

Happily the results of Pearson, Ploetz and Snow on the selective death rate have recently been accorded a confirmation and extension to still another group of people—the Dutch—in some as yet unpublished investigations carried out by Dr. F. S. Crum of the Prudential Life Insurance Company, with the assistance of the distinguished mathematical statistician, Mr. Arne Fisher. By the kind permission of these gentlemen I am able to state the general results of these investigations in advance of their publication.

The Dutch Government publishes annually data which undoubtedly furnish the best available material now existing in the world for the purpose of determining whether or not there is a positive or negative correlation between infant mortality and the mortality in the immediately subsequent years of life. Fisher's mathematical analysis embraces a very large body of material, including nearly a million and a half births, and nearly a quarter of a million deaths of males occurring in the first five years of life. The Holland data make it possible to develop life tables for every cohort of births and this has been done in the 16 cohorts of males during the years 1901-1916. The data also make it possible to work up these life tables for urban areas and for rural areas. After carefully eliminating secular disturbances the Holland material appears to prove quite conclusively for the rural districts that there is a definite negative correlation, of significant

magnitude, between infant mortality and the mortality in the immediately subsequent years of life. The only place where positive correlation appears is in the four large cities of the country with more than a hundred thousand inhabitants each. Fisher makes the following point (in a letter to the present writer) in explanation of these positive correlations. He says:

> The larger cities are better equipped with hospital and clinical facilities than the smaller cities and the rural districts. More money is also spent on child welfare. Is it therefore not possible that many feeble lives who in the course of natural circumstances would have died in the first year of life are carried over into the second year of life by means of medical skill? But medicine cannot always surpass nature, and it might indeed be possible that among cohorts with a low mortality during the first two years of life there will be an increase of death rate in the following three years of life.

Altogether, we may regard the weight of present evidence as altogether preponderant in favor of the view *that the death rate of the earliest period of life is selective—eliminating the weak and leaving the strong.* From our present point of view it adds another broad class of evidential material to the proof of the proposition that inheritance is one of the strongest elements, if not indeed the dominating factor, in determining the duration of life of human beings.

VITAMINS AND FOOD DEFICIENCY DISEASES

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AMERICAN scientific men have been credited with lagging behind the progress shown in England and Europe in the domain of medicine. Surgery has come fully into its own, in the western hemisphere. But American medicine too often is held to be engaged solely in practising and teaching, and all too little in investigating. Its contributions to scientific knowledge are held to be meager and unimportant. Among many, one of the finest refutations of this mistaken notion is discovered in the impetus given by American scientists to our understanding of dietetics and food values, and the use of diet in the prevention and cure of disease. Strictly speaking, modern medicine has relatively little to do with drugs. Webster's definition of medicine is best, namely, the prevention, cure and alleviation of disease.

It has remained for American investigators to lead in showing how important is the rôle assumed by diet in the prevention, cure and alleviation of disease. The old dictum, "Feed a cold and starve a fever" has been reversed. Laboratory studies on the basis of exact measurements of energy requirements in the body under normal and pathologic conditions, have demonstrated that in the presence of fever, more energy is required, and that, if this additional energy is not furnished in an increased diet, it will be secured at the expense of serious inroads on the body reserves, and that such inroads result in definite symptoms and in abnormal physiologic processes which invariably tend to make the invading disease more dangerous.

Our appreciation of dietary requirements for health has advanced so that the term, a balanced diet, means considerably more than merely the provision of a sufficient energy supply. "Man shall not live by bread alone" is equally true of his physiologic mechanism. To-day a balanced diet implies of course that the body shall receive a sufficient quantity of energy from the food, that there shall be a proper number of calories of food energy per unit of body weight. It means a suitable distribution of this total caloric requirement between carbohydrate, fat and protein. It means also a proper mineral supply of inorganic salts. Water is a prime necessity for digestion, absorption and for cellular function. Four-fifths of the body weight is water and only one-tenth of the water in the body is found in the blood. Hence the necessity for sufficient water intake.

Since the epochal work of Emil Fischer, we now understand something still further of the mysteries of protein or nitrogenous metabolism. In food the protein molecule is extremely large and complex. In the process of digestion, through the action of digestive juices and enzymes, this molecule is broken down into relatively small units called amino acids. In digestion all forms of protein yield these ultimate amino acids or building stones. Less than a score of amino acids are known, but all proteins are composed of various groupings of two or more of these building stones. Thus it is easily understood that for repair of body tissue and for growth, there must be a correct selection of amino acids. No protein contains all the amino acids and many proteins lack certain amino acids which are absolutely essential for growth or for maintenance of body cells. Thus in practical dietetics it is necessary to do more than secure merely a certain total quantity of protein per day. That protein must be so selected, in quantity and quality, as to supply the required amino acids or ultimate building stones in correct variety and quantity. This explains why proteins of cereal or vegetable origin may not entirely substitute with safety for proteins of animal origin.

For some time it was supposed that nutrition consisted solely in the absorption and utilization by the body, either for energy or for tissue building, of food stuffs which, according to the preceding description, had been adequately prepared through the medium of digestion. These food stuffs seemed to have been placed on a level of chemical and mechanical exactitude by the wonderful development of physiological chemistry to which reference has been made, and by the classification of food into the great divisions of proteins (amino acids), fats, carbohydrates, minerals and water. The rapidly advancing and changing conception of food deficiency diseases has, however, led to and accompanied an extension of the classification of food elements to include certain as yet largely unknown substances, called vitamins, which have a definite controlling influence on nutrition, health and growth. Imbalance, or lack of some or all of this group, is believed to eventuate in physiological perversions which proceed to clinical disease. This conception parallels the idea of physiologic perversions due to deficiency in the earlier recognized food elements, as observed in starvation, or in the results of the body's inability to burn carbo-hydrate in diabetes.

In general food deficiency may be said to act in one of three ways to produce a departure from normal health and nutrition. It may result simply in mal-nutrition, or better, poor nutrition, from insufficient supply of the particular food elements lacking. This form of mal-nutrition is automatically more or less compensated for by increased utilization of other food elements. Such a compensatory use of other food elements occurs least in the case of protein insufficiency. Proteins may be

spared in bodily nutrition by increased utilization of carbo-hydrate and fat, and thus the minimum necessary intake of nitrogenous food may be lowered, but no other food can actually and entirely replace the function of protein.

In the second place, a deficiency of some food element may cause a general disturbance of metabolism. This is illustrated by the condition of acid intoxication, or acidosis, which may result from a diet excessive in fat and deficient in carbo-hydrate, as seen, for instance in certain types of infantile acidosis, and in the dangerous and often fatal acidosis of diabetes. In the third place, a food deficiency may predispose to secondary factors which are directly responsible for disease. Thus a condition of under-nourishment from general deficiency or starvation, predisposes to infection. Again deficiency of a particular food element may result in a selective mal-nutrition of some organ or system of the body, as illustrated in the nerve degenerations of beriberi.

Thus it is evident that the problem of food deficiency is no simple one, but that it is complicated by selective results produced in the organism, by secondary factors which may become operative in the presence of the deficiency, and by obscure inter-relations and balances of nutritive equilibrium which easily may be disturbed by a variation in the component food elements. Here too must be considered the activity of various physiologic factors of safety in the animal body, which nature providently furnishes as additional safeguards against disruption of the delicate and sensitive adjustment necessary for health. Such a factor of safety is seen in the mechanism involved in maintaining proper alkalinity of the blood serum, thus preventing acidosis. Another illustration is the detoxifying function of the liver whereby various chemical poisons, if they happen to gain access to the blood stream, are automatically neutralized.

Given, then, a dietary constructed with due regard for water, mineral salts, carbo-hydrate, fat and protein building stones, one additional fact must yet be taken into account to secure a perfectly balanced food supply. This final factor has reference to the protein-like substances called vitamins, or accessory food substances. At present three types of these substances are recognized and a proper proportion of each is required to prevent serious derangement of the metabolism. It is not known whether these substances act in the body in a definite constructive fashion, entering themselves into the chemistry of metabolic processes, whether they act as catalytes, stimulating and originating changes in other substances but taking no chemical part themselves.

Two general lines of investigation are responsible for our present knowledge of vitamins. For a considerable time these two lines seemed contradictory, but they have gradually converged and afforded perspective and unity to our entire conception. The name "vitamin" was coined in 1911 by Casimir Funk for a substance occurring in rice

polishings and yeast, which appeared to cure neuritis in birds and beriberi in man. This line of investigation was based on the earlier work of Eijkman in the Dutch East Indies, who, in 1897, had demonstrated a multiple neuritis in fowls fed on a polished rice diet and observed that this neuritis was curable by feeding rice polishings. In 1907, Fraser and Stanton, American workers in the Philippines, found that an alcoholic extract of rice polishings would cure experimental neuritis. Funk found the same to be true for yeast and from an imperfect knowledge of the chemistry of the substance, called it vitamin, an amino or basic nitrogenous body necessary for normal life. Thus the study of beriberi led to the name and conception of vitamins. Hopkins has suggested "accessory food substances" as a better term, and Graham Lusk "food hormones." Both suggestions have merit and the word vitamin has definite disadvantages, but priority, common usage and brevity have established vitamin as the term of choice and so it doubtless will remain.

The second line of investigation developed on the basis of nutritional studies by McCollum and his associates, by Osborne and Mendel, and others, which showed that various foods of approximately similar caloric value and total content of fat, carbo-hydrate and protein, exhibited an enormous variation in their ability to maintain life and promote growth. These experiments, in huge numbers, were carried out on animals and the results threw brilliant light on the problems of the food deficiency diseases as observed clinically in human-kind. It was found that certain food stuffs produced results in growth and nutrition out of all proportion to their quantitative or caloric value. Out of a great mass of carefully directed investigation, there crystallized in 1915 the recognition of two groups of vitamins, named by McCollum "fat soluble A" and "water soluble B." More recently evidence has accumulated in favor of a third group of vitamins called "water soluble C." This C group has to do with the prevention of scurvy. It is now possible by specialized chemical procedures to concentrate and isolate vitamins of these three groups.

The exact chemical nature of vitamins is unknown. The exact relation of vitamin deficiency is not in all cases clear. We can say, however, that growth, beriberi and xerophthalmia are directly related to A and B factors. Scurvy seems definitely connected with deficiency of the C vitamin. Evidence has accumulated that pellagra belongs with the vitamin deficiencies, and then follow a number of less clearly defined conditions, such as rickets, various forms of infantile and adult mal-nutrition, anemia and marasmus. These latter seem to be associated with an excess of carbo-hydrate in the diet, together with an insufficiency of mineral and animal constituents. While many cases of eczema now are known to be caused by a skin reaction to certain specific proteins of the food, still a large percentage of eczema depends

on or is greatly influenced by an excess of fat or carbo-hydrate. The last statement applies also to acne or "pimples". A certain form of acid poisoning in babies is caused by excess fat in the diet. To a great degree dietary irregularities are responsible for the uric acid abnormalities of gout, and finally no small proportion of cases of constipation follow a diet lacking in bulk or in cellulose.

Again, as has been mentioned, symptoms which had been ascribed to certain diseases are found to be due in all probability to defective nutrition, again illustrating the relation of food deficiency to disease production. For example, diarrhea, delirium and the so-called typhoid state have been considered integral elements of the natural history of typhoid fever. However, since the introduction of the high calory diet in typhoid, these symptoms are usually mild or in abeyance. The inference is justifiable that these symptoms are due, not to the typhoid infection, but to a food deficiency resulting in mal-nutrition. This deficiency is doubtless qualitative as well as quantitative. It will be found probably that many symptoms of many diseases are not at all pathognomonic of those diseases, but are characteristic of and common to some form of unbalanced diet.

There is good reason to believe that the primary cause for the onset of many diseases will be found eventually to lie with a dietetic deficiency of some sort. In the case of amebic dysentery, for instance, McCarrison in Coonoor, India, found experimentally on monkeys that the disease appeared in the presence of a food deficiency where it did not develop when the monkeys were well nourished on a balanced diet. There is sound judgment in McCarrison's conclusion "emphasizing the importance in practice of a study of the dietary history of the case, believing as I now do that bacterial agencies are often but weeds which flourish in soil made ready for them by dietary defects, and believing also that in the fuller comprehension of the science of dietetics we shall understand more perfectly the beginning of disease and its therapy."

One further illustration of the vast importance of food deficiency in social, economic and health welfare, lies in the situation stressed by Dr. Mazyck P. Ravenel, president of the American Public Health Association. Dr. Ravenel advocates the cultivation of a wholesome fear of those diseases and infections which, while not apt to result in death, yet are attended by a high degree of social inefficiency and invalidism. Less emphasis on mortality and more emphasis on invalidism figures gives a better estimate of the real human seriousness of disease. Malaria destroyed Greece and Rome, and malaria has not a high death rate. Influenza struck the world with shocking severity, but it left no social scar on the race, no aftermath of invalidism and social inefficiency. Chronic exhaustive diseases like malaria, hookworm, tubercu-

losis and syphilis are, after all, the greatest scourges of mankind, and their social and economic cost is highest.

In two ways food deficiency is closely related to the considerations detailed in the last paragraph. In the first place, the greatest single predisposing factor to the development of the chronic exhaustive type of disease is food deficiency and mal-nutrition. Secondly, just as in the case of specific diseases, the more serious human losses are due to invalidism and social inefficiency, so in the realm of nutrition, after all is said, the loss from the definite specific deficiency diseases does not bulk so great as the huge loss from vague ill-health and more or less severe invalidism resulting from unbalanced or insufficient diet. In this connection are to be noted the nutritional dangers attendant on the increasing use of food substitutes. Examples of such substitutes are cotton seed oil for olive oil, or cod liver oil, margarines for butter, and the use of milk powders. Food substitutes are very important and may be very dangerous on a broad scale. The tendency in America is to excessive utilization of meats and sweets, with a subnormal employment of vegetables, fruits and dairy products. Such racial, local or individual aberrations of diet are vastly important and to an unbelievable degree are concerned with a sub-normal status socially, economically and in health. From such a sketchy survey it is evident that the science of dietetics promises to become ever more important in the treatment and prevention of disease, and as essential from the sanitary and public health point of view as for the individual man or woman.

We turn now to that smaller group of diseases which have been noted as having a direct relation to vitamin deficiency. While we can not state with absolute accuracy the specific element lacking in each case, we can assert with complete safety that they are due to an unbalanced or faulty diet, and that certain dietary procedures will serve adequately to prevent and to cure them.

Having clearly in mind what is meant by the term vitamin, and in spite of the disadvantages of the name, using it in a generic sense, it is next in order to consider why there should be clinical differences in disease types arising from a common etiology. Why should a vitamin deficiency in one case eventuate in beriberi, in another in pellagra and in a third in scurvy? While this question can not be fully answered at present, certain suggestive hypotheses may be predicated. As already explained, there is ground for the belief that vitamins are not unit substances, but represent a group chemically related and unstable, which may well have certain inter-relations necessary for their physiologic functioning. Thus absence of one type might be associated with a special clinical syndrome.

Recalling the three methods in which food deficiency may disturb the nutritional status, it is apparent that a vitamin deficiency may also produce differing clinical results by virtue of secondary factors which

may become operative under varying conditions of climate, general condition of patient, concurrent infection, age—in short, that the effect of the vitamin deficiency may be influenced or even determined by all manner of extraneous circumstances, whose operation may conceivably be initiated or modified by the deficiency. It is not unlikely that the general type of caloric food supply used may be of importance, since we find for instance that beriberi is most common in rice eaters, and that pellagra is usually associated with maize.

Before discussing the common pathologic features of the deficiency diseases and methods of cure and prevention, it may be well to rehearse briefly the clinical picture of scurvy, beriberi and pellagra, with some suggestions of the experimental basis for believing them due to a food deficiency.

Scurvy

Armies and ships have suffered notoriously from scurvy. The name suggests the days of early exploration, long voyages and sailing ships. Whalers, fishermen, armies, sailors, explorers—all have feared and fought scurvy. As will be seen, the very circumstances which now are best explained as due to a food deficiency, were once considered conclusive proof of the disease being an infection and this view has prevailed to some extent, as in Russia, for example, almost to the present time. Its true nature was apprehended by the British much earlier as witnessed by the virtual disappearance of scurvy in the British navy since the regular rationing of lime juice began in 1795.

Scurvy is characterized by a pronounced inclination to hemorrhage, with soft, spongy bleeding gums, and hemorrhage under the skin and from mucus membranes. Certain bony changes follow and a condition of progressive weakness and anemia. In children, hemorrhages are more apt to occur under the periosteum causing what is often diagnosed by the mother as "rheumatism of the legs", and characteristic skeletal changes are seen. The condition rapidly improves upon the addition of anti-scorbutic articles to the diet. Fresh meat and vegetables, especially with limes, lemons, onions, etc., are quickly curative except in the extreme stage.

Comrie has recently detailed his experiences while on duty with British troops in northern Russia in 1919. Scurvy appeared on a large scale among prisoners and natives. After several months on a diet deficient in protein, vegetables and fresh foods, the disease appeared in wholesale fashion. Its effects were doubtless intensified by the crowded prisons, general poor surroundings, and the long Arctic night. A purpuric rash on the legs usually came first, accompanied by mental depression, loss of energy and weakness. Bleeding gums, swollen ankles, and hemmorrhages into muscles and joints rapidly followed. Pain was noticeably present. Recovery was rapid with correction of the diet

alone, and in a month's time the victims showed few sequels of the disease. An effective anti-scorbutic was found in germinated peas or beans. Preserved lime juice was useless.

Another striking outbreak of scorbutic disease occurred as reported by Siccardi, in Italian troops serving at high altitudes in the Alps. In the summer of 1916 these troops suffered from a transient epidemic of a hemorrhagic form of scurvy. These hemorrhages were noted among those sick of other diseases as well as in men who had no other complaint. The disease was traced to an unbalanced diet, in the presence of cold, and ill ventilated under-ground quarters, and it was easily controlled by proper diet and rest.

Infantile scurvy is of surprising frequency especially in cities, where the widespread use of Pasteurized milk always brings danger of scurvy unless corrected by anti-scorbutics. Infantile scurvy is not common in the advanced stage characterized by very poor nutrition, "rheumatism of the legs," and bleeding spongy gums. But of surprising frequency, especially in cities, is a status of more or less indistinct symptoms associated with failure to gain weight and a tendency to hemorrhage, especially beneath the skin and mucus membranes, irritability and fretfulness, and sometimes femoral tenderness. Pateurized milk should be corrected by the addition to the diet of orange juice. It must be remembered that the advantage of Pasteurization vastly overbalances its tendency to produce scurvy, and that this tendency is easily controlled by a simple means.

In the group of deficiency diseases mid-way between scurvy and beriberi should be mentioned a peculiar syndrome called "ship beriberi." This affection differs from beriberi in its lack of involvement of the peripheral nervous system and is related to scurvy by its tendency to hemorrhage. The Newfoundland fishermen suffer from a similar condition in which a beriberi-like dropsy is associated with sore, bleeding gums. On the Labrador, the Esquimaux are frequently victims of scurvy and beriberi.

Dr. John M. Little, writing from Newfoundland, has described a deficiency disease related in causation and also doubtless in pathology, to this group. It is known among the natives as kallak. Commenting on the need for proper vitamin content in the diet, Dr. Little states that it is largely unknown as to where the Esquimaux get the necessary ingredients for a balanced diet outside of meat. The meat supply comes from seals, caribou, birds and fish. In good seasons berries too, are abundant, and when frozen, keep well. Dr. Little points out a possible source of carbo-hydrate supply when either civilized foods are not to be had, or when there is a failure of the berry crop. He says that the great feast of the Esquimaux consists of a thick soup made of the blood and stomach contents of the caribou. The caribou

eats coarse vegetable matter such as lichens, moss, tree bark and small twigs, leaves and shoots, which are entirely unsuitable for the human stomach. The powerful digestive juices of the animal's stomach convert this coarse vegetable mass into forms which in turn can be acted upon by the more delicate digestive mechanism of man, and thus rendered assimilable. Thus is there secured the requisite vitamin supply from fresh vegetable sources.

Kallak appears on the Labrador in endemic form when there is a deficiency especially of seal meat and berries, resulting probably in a deficiency of the fat-soluble type of vitamins. It is in turn prevented and cured by an abundance of seal meat and berries. It shows itself in successive crops of a pustular erruption with intense itching. The disease tends to recovery as soon as a balanced diet is procured. Dr. Darling has described another variant of scurvy in the South African Rand, which has certain features approximating beriberi.

Beriberi

Beriberi is a disease of antiquity known and described in ancient China, and recorded as having attacked a Roman Army in Arabia before the Christian era. It is pre-eminently a disease of the Orient and Pacific islands, although now widespread in Africa and South America, and not infrequently reported from other countries. It is not unknown in San Francisco and other parts of the United States. Its common association with a predominant rice diet does not always hold true. An instance of this is afforded by Draper, who in 1916 recounted nine early cases in a crew of fourteen men on a Norwegian bark touching at St. Helena. Here the victims had eaten sparingly of rice and had an abundance of fresh vegetables. An evidently beriberic diet was not demonstrable. Such instances lend credence to the parasitic theory of causation, held especially by certain English writers. For example, one of the most competent sanitarians in the Far East, Dr. Arthur Stanley, health officer of Shanghai, wrote in his 1914 report, "The cause of this disease (beriberi) remains under close observation, though up to the present wrapped in obscurity. The evidence preponderates in favor of the disease being an infectious one, having no direct relation to food but infective through body vermin." This view, however, is not tenable in relation to the American and Dutch results in the Philippines and East Indies.

Beriberi can now be classified accurately as a food deficiency disease caused by a lack of neuritis-preventing vitamin, water soluble B, in the food. Its occurrence in rice-eaters is associated with the use of polished rice, where the pericarp is removed from the grain. In this pericarp is the vitamin. The pericarp also contains an important fraction of phosphorus and the relative quantity of vitamin present can be measured by the quantity of phosphorus. Less than 0.4 per

cent. of phosphorus pentoxide indicates a dangerous vitamin deficiency, if rice is the chief article of diet.

Beriberi is essentially a disease of the nervous system and shows itself in poly-neuritis, accompanied by an edema especially of the lower extremities and a weakened heart. This last is an important differential point, and the extreme tendency to cardiac failure is most serious. The disease may be acute and fatal within a few days or it may pursue a chronic course. The term beriberi, includes a large and more or less ill-defined group of diseases which have not yet been carefully separated. There are various types and all degrees of intensity, now one and now another symptom outstanding. Many forms are on the borderline of scurvy and may represent a combined deficiency. If the neuritis and nerve damage are sufficiently extensive, there may be a residual paralysis which long outlasts the original disease. Beriberi is often of importance in its incipient or larval form, because it predisposes to other diseases and in turn, larval beriberi may suddenly fulminate under the excitation of some other acute disorder. Thus beriberi is remarkably frequent in association with acute dysentery. It is interesting to note that beriberi is almost unique among tropical diseases in having no features of laboratory importance. The diagnosis rests solely on clinical data and the laboratory findings are entirely negative or normal.

Pellagra

Pellagra is an endemic disease of modern history. It is not definitely known to have been recognized earlier than the 18th century, when it was described in Italy and Spain as of rather wide distribution. From the first reports in Italy it has been ascribed to a maize dietary. It was early identified with "Alpine scurvy". The disease was recognized in Egypt in the first half of the nineteenth century, and since then in France and other parts of Europe. It was first described in the United States in 1907 but had undoubtedly existed there for an indefinite time preceding. It is estimated that there are 125,000 cases in the United States at present. According to Goldberger of the U. S. Public Health Service, who, with his associates has studied the disease exhaustively, it is one of the foremost causes of death in the southern states, in 1916 ranking fourth in Mississippi, third in Alabama, second in South Carolina. Not only this, but it is responsible for an unguessed total of sickness and physical inefficiency in addition. Its actual death rate is about 5 per cent. The relative infrequency of pellagra outside the endemic area in the United States will probably be found related to the dietary deficiency which we believe is its cause.

The incidence of pellagra has a close relationship to economic circumstances and living conditions. High food costs and hard times lead to poor sanitary and unhygienic living conditions, which as al-

ways, reach their climax where housing and sanitary knowledge are meager. This tends to enforce a dietary favorable to the development of pellagra especially in the south where corn, fat pork and certain types of vegetable food, are associated with a dearth of lean fresh meat, milk, eggs and green fresh vegetables. Following the economic conditions of 1914, the incidence of pellagra rose in 1915, again to decline as conditions improved a year later. Again in 1917 an increase was observed, due to like causes, and accurately foretold by the scientists of the Public Health Service.

The symptoms of pellagra are in three groups, appearing respectively in the skin, gastro-intestinal tract and nervous system. Pellagra, or "rough skin," derives its name from an early observation of the skin. Roughened, dry patches of erythema, often superficially similar to sunburn, and symmetrically located, are the characteristic lesions. These areas usually are on surfaces exposed to the sun, but not necessarily so. The second major group of symptoms arises from the gastro-intestinal tract, and includes various forms of indigestion, diarrhea, increased acidity of the stomach, and sore mouth. The mouth condition, in fact, is suggestive of sprue. Again, the tender bleeding gums are suspicious of scurvy, and represent a relationship to that disease as well as explaining the old name of "Alpine scurvy". The third major group of symptoms is referable to the nervous system. Fortunately not all cases of pellagra progress to insanity. But from the first a neurasthenic condition is present to which are added gradually various paresthesias, changes in reflexes, suicidal attempts, tremors, and, in the final stages, a confusional insanity.

All of these symptoms show a remarkable vernal periodicity, advancing in the springtime and receding toward autumn and winter. Not infrequently for several years the only symptoms noted will appear in the spring and not be related to each other by the patient. Fever is not present typically, except late in the disease and probably represents intercurrent infection due to the weakened organism. The outlook in pellagra is very dark unless the patient can be subjected to proper dietary treatment. Under such proper conditions, improvement and cure ensue even in advanced cases. Treatment cannot repair, of course, broken down tissues or remove organic changes in the brain and elsewhere.

Other Deficiency Diseases

As has been pointed out, there is a heterogeneous group of diseases and overlapping clinical conditions caused by deficiency of vitamin supply. One of the most definite of these is xerophthalmia, in which failing vision and blindness are produced by increasing opacity of the cornea. H. Gideon Wells has described the occurrence of xerophthalmia on a large scale among the famine sufferers of Roumania

where it was promptly relieved by the administration of cod liver oil. The malady is evidently due to deficiency of the fat soluble A vitamin. Another and perhaps less clearly defined disorder is war edema, war dropsy, famine edema, or perhaps best, in the words of Wells, "nutritional dropsy". It was observed on a huge scale among prisoners of war in Germany and rather in those who were compelled to work while undernourished than among those who were merely underfed. Decreased protein and caloric intake are associated. It was frequently seen in conjunction with xerophthalmia. Another affection, similar in some points to beriberi and again to war edema, was reported from northern Africa during the Great War. This nutritional edema is probably identical with the dropsy occurring in infants fed for long periods on a highly carbonaceous diet.

It has been suggested that, succeeding an obvious state of mal-nutrition in infantile life, there may appear some disorder in later life with no apparent relation to the causal mal-nutrition. As an example of this, indications are cited that dental caries is produced by a deficiency in early life of a vitamin similar to fat soluble A. More recently most interesting experiments have been conducted by W. G. Karr, who finds a striking relation between the presence of water soluble B vitamin and appetite. This appetite-provoking vitamin is found in abundance in tomatoes and brewers' yeast.

Comparative Pathology

The beriberi-scurvy group of deficiency diseases exhibit a striking relationship in morbid anatomy. Darling working in the Canal Zone in 1915, graphically portrayed this relation in a chart of overlapping circles whose centers were arranged in a straight line. The chief pathologic findings were grouped in a series along the straight line, ranging from palsy, through dropsy, cardiac weakness and degeneration, nerve degenerations, spongy gums, hemorrhages, bone lesions, to the lesions at bone ends which are so notable a feature of rickets and often of scurvy. The overlapping circles each of which embraced several of the pathologic series, began with classical beriberi and ranged through ship beriberi, scurvy, guinea pig scurvy, and infant scurvy to rickets.

There is little doubt that beriberi is a disease group and not a fixed disease entity. The same is unquestionably true of scurvy and doubtless the other food deficiency diseases will eventually appear as types, varying with the relative imbalance of vitamins, and modified by other nutritional and environmental factors. As has been indicated, scurvy and beriberi have many points of pathologic similarity. Among these are especially to be noted the nerve degenerations and enlargement of the right heart. Pellagra differs somewhat in having a triple complex in pathology and symptoms, involving nervous system, gastro-intes-

tinal tract and skin. It is of interest that scurvy often shows a reddened, roughened skin. The deficiency diseases are characteristically afebrile.

It is known that after eating buckwheat, many persons suffer from a severe dermatitis on exposing the skin to bright light. A similar explanation has been offered very plausibly for the rash in pellagra. It has been suggested, too, that the mental complex in pellagra is induced by bright light in a nervous system predisposed by a nutritional deficiency. The role of light, or actinic energy, in the causation and treatment of skin rashes, even in the acute infectious diseases such as smallpox, and scarlatina, is but poorly understood.

Darling found that in Rand scurvy, occurring with great frequency in South Africa and Rhodesia, there was a striking eccentric hypertrophy of the right heart, along with severe degenerations of the vagus nerve. Hess has noted the frequency of dilated right heart in infantile scurvy. There is often also associated a cardio-respiratory disturbance which still further illustrates the involvement of the nervous system. Such findings indicate a close relation between scurvy and the beriberi group. Darling calls attention to the contrast between beriberi as a neuro-cachexia, and rickets as an osteo-cachexia.

Vitamins and Diet

The fat soluble vitamins are found abundantly in butter, eggyolk and cod liver oil. The water soluble vitamins are found in yeast, and in many green vegetables and whole grains. There is reason for believing that vitamins can not be constructed either by animals or by plants, but that they are a product of bacterial action. Their presence is necessary for the growth of yeast and the rate of yeast growth has been used as a measure of the quantity of vitamins present in food substances. Vitamins are destroyed by heat, either excessive or of moderate intensity but long continued.

An interesting study of vitamins in bread was made by Voegtlin, Sullivan and Myers, of the U. S. Public Health Service, in connection with investigations on pellagra. They were impressed with the marked reduction in two decades of the vitamin content in the dietary of the population studied (Spartanburg county, South Carolina). They ascribed this reduction to three causes. First, reduction in usage of vitamin-rich foods such as fresh meats, eggs and milk, due to advancing cost. Second, increased use of highly milled cereals, made from wheat and corn, in which the vitamin-rich pericarp, husk and kernel are largely removed. Third, the increased use of baking soda in bread-making. The danger from soda lies in the fact that too often it is used to raise bread in place of yeast, and is not neutralized by acid as with sour milk. The soda apparently destroys the vitamin of the grain and this increases the deficiency of the excessively

milled grain. The use of soda to soften beans and other foods in cookery, has an equally destructive result.

It is evident that the use of highly milled grains is to be condemned. The extensive utilization of whole grain products during the war was a most beneficial modification of our national dietary, and should be continued. Its benefits pertain to the stimulating effect on the teeth, the avoidance of a concentrated and costive diet, and the provision of more vitamins.

Under ordinary circumstances no particular attention is required to the practical details of securing sufficient vitamin content in the dietary of the average individual in this country. But in the endemic pellagra district, or where for any reason a varied supply of fresh foods is not to be had, the securing of the necessary vitamins becomes a matter of concern. Such a diet should include yeast bread made from the whole grain. If rice is used to any considerable extent, it should be undermilled, with a high phosphorus fraction. At least once weekly, legumes such as beans or peas should be served. Fresh fruit and vegetables should appear several times a week. Barley is especially desirable and should be added to all soups. Yellow or water ground cornmeal is preferable to the white variety. White potatoes and fresh meat also should be included at least weekly, and better once daily. So far as possible canned food should be discarded.

It may not be amiss to warn against commercial preparations of vitamins which are beginning to appear on the market. Under ordinary circumstances of life there is no need for such preparations. It is questionable whether any circumstances at present justify their use. Further than this, the chemical instability of vitamins makes it difficult to say under what conditions of preparation and preservation, their potency will be maintained. Then, too, since there is no approved method of standardization of vitamins, there is consequently no check on adulteration of commercial preparations. It seems probable that the appearance of vitamin preparations on the market, coupled with the present scientific and popular interest in the subject, will lead to an exuberant advertising campaign parallel to the exploitation of starch-free foods for diabetics. Among these latter, a small minority alone are found on analysis to be what they claim.

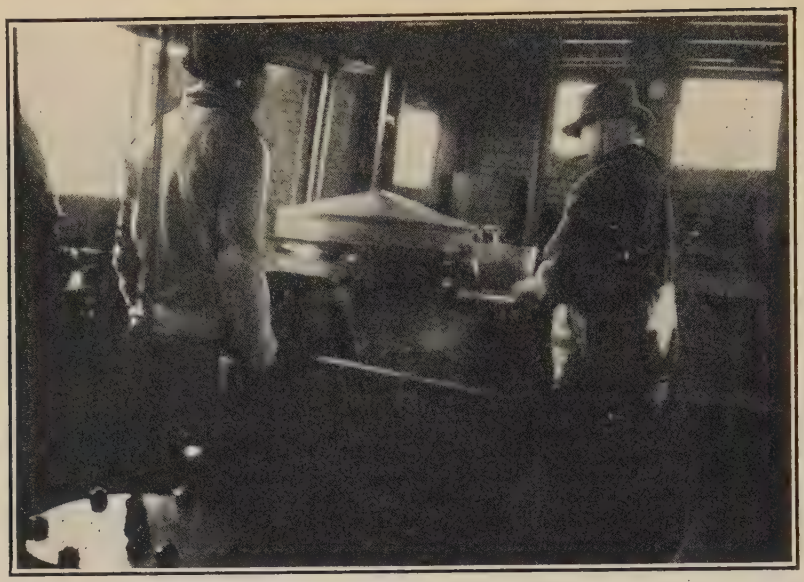
Conclusion

In summary, a new and important chapter is being written in our knowledge of nutrition, and to the classical requirements for a balanced dietary, has been added the requirement of a group of substances called vitamins. Vitamins are essential for growth, maintenance and reproduction of the human body, and lack of them leads to definite disease on a basis of mal-nutrition.

FISHING IN LAKE MICHIGAN

By A. S. Pearse

THE Great Lakes have rare scientific interest. Much of their history has already been written by geologists, geographers, and hydrographers — to say nothing of historians, novelists, and poets. This history contains thrilling chapters about glacier-built hills, the scouring out of valleys, and changes in great drainage systems. The evidence for these has been gleaned from sedimentary deposits, fossil beaches, and other enchanted castles where facts are condemned to remain unknown until scientific knights set them free and they turn into the most beautiful of fairy princesses—knowledge. It seems remarkable that biologists have so long neglected the opportunities that await research in these great bodies of water. Sordid commerce should have urged science to take up such investigation. There is "money"



THE MACHINE FOR HAULING NETS

in the Great Lakes, and commerce must always depend on science for the exploration, conservation and improvement of its resources. The fisheries of the Great Lakes bring in more than ten million dollars each year and the chief contributors are Lake Erie and Lake Michigan.[1]

The men who fish in the Great Lakes have the picturesqueness which is characteristic of deep water fishermen the world over. The danger and uncertainty of "open water" fishing give it the touch of romance that attracts bold spirits who like to take chances. The life is hard, but it may, and usually does, give rich rewards to those who follow it with industry, courage, and common sense. Fishermen are often "rough on the outside", but their life and training make them honest, independent and usually more thoughtfully courteous than those who have acquired "polish" in drawing rooms. One who has fished for a livelihood seldom goes back to the humdrum of a safe life on land. To give some idea of what a fisherman does each day on Lake Michigan the following description of a trip that the writer took as a guest on board the "Albert C. Kalmbach" is given:

On July 26 I got up at half past four and made my way through the deserted streets of Sturgeon Bay to the dock. A brisk wind was blowing in from Green Bay and the sky was overcast. Frank Higgins and his partner, Bill, were alrady loading boxes on board the "Albert C." when I arrived. "Boxes" are really trays and each holds about 1,600

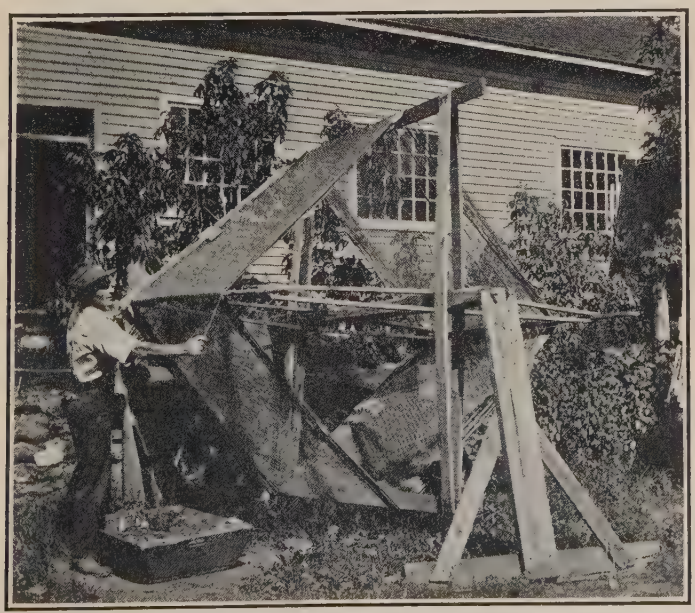
[1]According to the latest Report of the United States Bureau of Fisheries the value of the fisheries in these two lakes for the year 1917 was $4,332,767 and $4,038,927 respectively.

lineal feet of gill net. This morning the "boys" were loading "small mesh" nets, for they were going out after chubs and bloaters in the deepest part of Lake Michigan. As they worked I looked over the boat. The "Albert C." had been in the water less than two months and was a fine example of the type of boat now in growing favor with lake fishermen. Years ago fishing tugs were in common use. But tugs are expensive to maintain and, as fishermen to man them grow harder to find, they are gradually being superceded by little gasoline boats. The "Albert C." measured forty-five feet in length and had twelve feet of beam. In the center of her cabin was a shining new two-cylinder Kahlenberg engine which cost $2,500 and would delight the heart of any fisherman—a heavy duty engine; not speedy, but to be relied upon in a storm. Except for the little platform forward for the man at the wheel, the remainder of the cabin was devoted to fishing tackle. Oilskins and coiled lines hung on the walls and boxes of nets were piled on the floor aft. A gasoline hoist for hauling the nets occupied the space on the left side of the cabin forward.

As soon as the boxes were stowed Bill lighted the torches at the tops of the cylinders. When "she" was hot he "turned her over" and we started. We backed out of the slip just after five o'clock, went under the bridge, and set our course toward the head of Sturgeon Bay. A dirty fishing-boat named "White Swan" tried to race us, but Bill "let her out a notch" and we soon left the upstart behind.

"Ain't that an engine?" said Bill.

At a quarter of six we passed the lighthouse and were on Lake Michigan. A noisy flock of herring gulls greeted us. These birds fol-



PUTTING THE GILL NET ON A REEL

lowed the boat all day, continually on the alert for fish or scraps. For nearly two hours Frank ran "NNE". It began to rain, the wind freshened and stirred up the lake. Toward ten o'clock, when we were about twelve miles offshore, Frank sang out:

"There's one'."

I peered in the direction he indicated but could see nothing. As we came close, however, I made out a couple of tattered squares of canvas waving from a pole which projected from the top of a wooden

A—SETTING NETS OFF THE STEM OF THE BOAT
B—A TROUT JUST OUT OF THE WATER
C—A LAKE TROUT

buoy. The boys put on their oilskins. As the buoy came alongside Frank tried to haul it in, but the waves were too much for him, and he missed it. We circled around and, approaching from a little better angle, the buoy came on board. Bill quickly started the hoist, and Frank threw the line that had been fastened to the buoy over it. The way the little fingers on the hoisting wheel handle lines and nets is almost uncanny. The wheel is horizontal and as it revolves the fingers around its margin take hold on one side and let go on the other. When a line is placed over the wheel it is grasped and pulled across from one side to the other. In this way the line came into the cabin and brought up a "string" of nets from the bottom.

The nets that we pulled had been set for seven days at depths of sixty-five to eighty fathoms. All of them were tied together in "strings" of four boxes each. A line leading up to a flag buoy was attached at each end of a string. Gill nets stand up from the bottom like a tennis net; weighted along the lower side with leads and stretched by the pull of corks along the upper side. Fishes swim into the meshes while moving along near the bottom and become entangled. Most of those brought up in the nets are still alive. The deeper waters of lakes are usually cold and fishes may live for a long time after being caught.

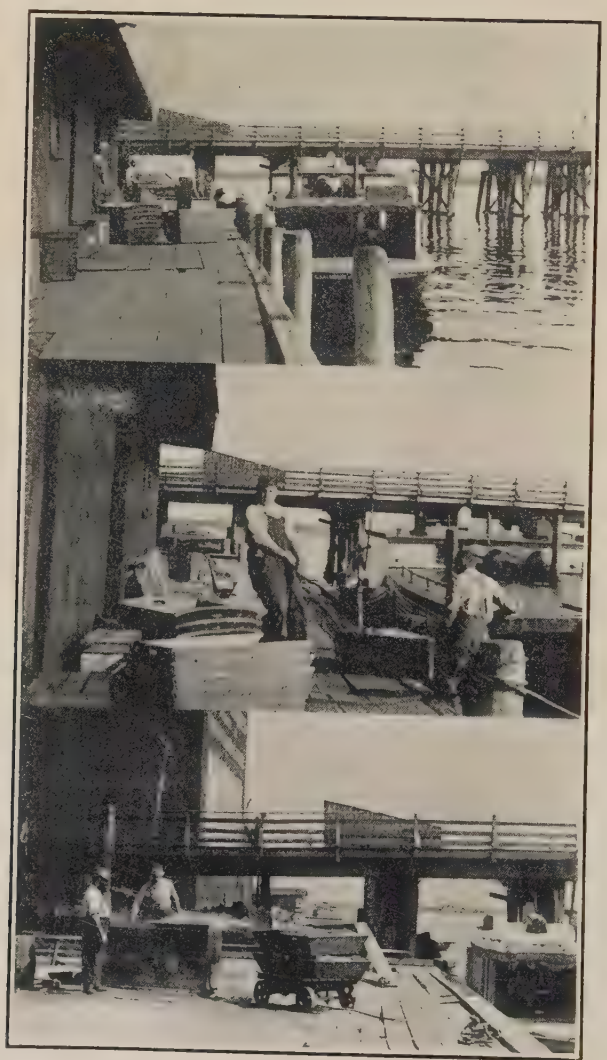
Bill stood by the port where the lines and nets came in and kept them running smoothly around the hoisting wheel. Frank dextrously took the fishes from the net, using a short awl in order to save his fingers from pricks and cuts. He also extracted cinders and twigs from the net before coiling it down in the box in front of him.

By half past twelve twenty boxes had been hauled and nets from the same number reset off the stern of the boat. The catch consisted of about 500 lake trout, 200 bloaters, 150 chubs, 12 lawyers, 2 blackfins, and 5 ugly little cottids, which the fishermen call "stonerollers". The lawyers, stonerollers, and a few of the other fishes were thrown back into the lake—to the great delight of the gulls.

I ate my lunch at eleven o'clock, but Frank and Bill did not get theirs until all the nets were set. On the way home Bill ran the boat, while Frank cleaned the catch. Frank performed his work with remarkable speed. Catching up a fish by its head, he laid it on a board; one movement with the knife removed the gills, another slashed open the ventral wall of the body, and a third threw out the visceral organs. At 3:10 P. M. we were back at the dock with the catch of the day cleaned and the cabin floor scrubbed.

I was glad to go on shore and rest, having lost my lunch in the lake, but the crew still had two or three hours work ahead. The nets had to be boiled, to keep them from rotting, and then spread on reels to dry. After that the nets to be set on the following day were to be wound off the reels into boxes. While the boat crew were looking after the nets, the men in the fish market sorted the fish and put them on ice.

Kalmbach's fish market, in Sturgeon Bay, is an interesting place. It is well equipped to care for all sorts of lake fishes and does both wholesale and retail business. The owner operates three boats which fish on a co-operative basis, the owner furnishing nets and boats and the crew getting a certain percentage of the catch. At the market fishes from pound nets are bought, mostly sheepshead and perch, and line fishermen bring in a number of pickerel each day. The retail departments sells fish to all who will buy—tattered urchins, pretty girls, hotel managers, dames in silken gowns come for fresh fish. Behind the market are three modern smoke houses where delectable chubs are prepared.



A.

B.

C.

A—FISHING BOAT AT THE LOCK
B—UNLOADING BOXES OF LAKE FISH
C—BOILING NETS TO KEEP THEM FROM ROTTING

According to the Report of the United States Commissioner of Fisheries for 1918 the value of the equipment used for fishing in Lake Michigan in 1917 amounted to $4,038,927. This amount includes boats, nets, traps, lines, shore property, and the cash capital necessary for operation. The returns from the fisheries amounted to $2,270,859—a very fair amount for the capital invested. The fishes furnishing this revenue were as follows:

Fish.	Pounds	Value.
Trout, fresh	8,679,845	$856,228.00
Trout, salted	12,820	259.00
Ciscoes (chubs, bloaters, etc.), fresh	15,341,588	708,038.00
Ciscoes, salted and smoked	2,917,766	139,344.00
Whitefish, fresh	3,145,780	327,991.00
Whitefish, salted	28,048	2,174.00
Perch, fresh	2,361,071	116,419.00
Perch, salted	1,725	81.00
Suckers, fresh	2,103,163	74,803.00
Suckers, salted	14,110	625.00
Wall-eyed pike	132,024	18,445.00
Carp	246,503	7,500.00
Catfish and bullheads	164,466	6,627.00
Pickerel	40,597	3,375.00
Sturgeon, Caviar	346	904.00
Sturgeon	10,805	2,517.00
Crawfish	80,495	4,427.00
Lawyer	166,785	1,436.00
Rock bass	1,714	137.00
Buffalo	1,290	56.00

During 1917 the Great Lakes as a whole yielded $6,416,477 on a total investment of $10,732,879. In Lake Michigan fourteen-fifteenths of the product of the fisheries came from the species which were caught in deep water. In Lake Erie, which is shallower, more than half the value of the fisheries also came from deep water. These lakes are in marked contrast to those in the course of the Mississippi River (Lake Pepin, Lake Keokuk)[2] where practically all the revenue comes from shallow water fishes—carp, buffalo, dogfish, catfishes, sheepshead, etc.

The fishes in Lake Michigan, which are of most value commercially, not only live on or near the bottom in deep water, but secure their food there. The soft bottom ooze, directly or indirectly, supports many detritus-feeding crustaceans (Pontoporeia, Mysis), clams (Sphaeridae), and insect larvae (mostly those of midges and may flies). The ciscoes, which are the most abundant fishes, the little cottids, the long-nosed sucker, and the whitefish feed largely on this bottom fauna. The trout and lawyer are primarily fish eaters. All these fishes are true deep-water species which have not, in the long period since glacial times, migrated to any extent into small inland lakes or into streams. They are at home in the cool depths of large lakes—where there is always low temperature, great pressure, and little or no light.

[2]Annual Report of the United States Commissioner of Fisheries to the Secretary of Commerce, pp. 78, 79.

CLEANING FISH ON THE WAY HOME

In the shallow waters of Lake Michigan the yellow perch is the most abundant species. It is rather omnivorous in its food habits, and is at home in a variety of habitats. These characteristics probably account for its abundance, but for some reason it does not go into deep water. The pickerel and pikes, which are common, are fish eaters. The sheepshead prefers snails to other foods. The other shallow water fishes which are of commercial importance are dependent on aquatic vegetation and the small animals which live among plants for food. Where vegetation is plentiful, as on swampy shores and at the mouths of rivers, they are abundant.

The ability of any body of water to produce large numbers of fishes depends primarily on its food resources. Somewhere in the shore vegetation, or in the microscopic life of the open water, or in the soft bottom mud there must be sufficient quantity to permit many fishes to maintain themselves from day to day. In Lake Michigan the great bulk of the fish food is in or near the bottom mud. Lake Erie with its larger area of shallow water has a different ratio of food resources and supports more shore fishes.

Lake Pepin, which is really not a true lake, but an expansion of the Mississippi River, has quite different food resources for fishes. The temperature of this lake is rather uniform at all depths and varies markedly with the seasons. The bottom shifts continually and does not support an abundant fauna. There are none of the deep water

fishes of lakes here, but many species peculiar to rivers—spoonbill, redhorses, quillbacks, sand sturgeon, etc. The fishes in Lake Pepin feed more on the microscopic organisms in the water and the foods dependent on aquatic vegetation than those in Lake Michigan. This means that the food resources for the fishes that man makes commercial use of are not in Lake Pepin (or in the Mississippi River) itself but along the shores and in the tributary swamps and lakes. A river is a highway to feeding grounds in lakes, swamps, or other habitats where fish foods are abundant and many fishes pass through it. The open water of a large river contains food for fishes as microscopic plankton organisms which float in the water, but its bottom is rather barren. The plankton is derived largely from swamps, ponds, shores, and is not developed in quantity in open water.

The problems relating to conservation of the food resources of the fishes which have commercial value are not the same in Lake Pepin and Lake Michigan. Because the former resembles a river in being largely dependent on is tributary lakes and swamps for food, it has a more precarious food supply. Rainfall controls the height of its water and the availability of its food resources. If the swamps along the Mississippi are ever filled or drained to further agriculture, the fisheries must suffer. If the access of fishes to tributary lakes is cut off by dams, or if the value of the river as a highway is destroyed by the presence of the wastes of commerce in the water, fishes must decrease in numbers. The continued success of the fisheries of the Mississippi depends largely on the conservation of the habitats tributary to the river itself. The fisheries in Lake Michigan have greater hope of continued stability because the food resources of the commer-

KALMBACH'S FISH MARKET

cial fishes are in deep water, where they are less likely to be depleted or destroyed by civilization.

The quantity of food available limits the number of fishes that can exist in a given volume of natural water, but whether fishes grow to large size is dependent on other factors. Stagnation or continued movement of the water may make it impossible for fishes to take advantage of foods which might otherwise be available. Parasites may be so abundant as to kill fishes or impede their growth. To state the case briefly—the number of fishes that may *exist* depends largely on food resources, but ability of fishes to grow to large size depends on the opportunities they have to live a healthy, normal life and *grow*. In this connection true lake habitats appear to have the advantage over those of rivers in their stability. The bottom and the deep water of Lake Michigan are dependable; they can be counted on to furnish about the same amount of food each year and to offer safe retreats. The food for fishes in Lake Pepin depends on rainfall and varies in different years. The variation in the height of the water also makes conditions for breeding and shelter uncertain.

The inland fisheries of the United States constitute great natural resources which ought to be as carefully and as scientifically conserved as farm lands, forests or water power. Yet in proportion to their value, they have received comparatively little attention. There are stations for hatching eggs, and cars for distributing young fishes for stocking inland waters. There are several well-equipped stations for the investigation of problems relating to marine fisheries. For fresh-water there is only one station where scientific work concerned with fisheries is undertaken—on the Mississippi River at Fairport, Iowa. This paper attempts to point out that the fundamental problems relating to the conservation of lake fishes are different from those in rivers.

THE GULLS FOLLOW THE FISHING BOATS ALL DAY LONG

THE PROGRESS OF SCIENCE

THE UTILIZATION AND CONSERVATION OF THE NATURAL RESOURCES OF THE UNITED STATES

No part of the world is more richly endowed by nature with all that is necessary for the building of a great nation than the United States; where have these natural resources been used in a more wasteful and prodigal manner? Our nation has prospered, but at the expense of a much larger consumption and loss of its resources than was necessary, and we are now actually confronted with the question as to how long that which remains will avail to maintain us. Our civilization is as dependent on power, light, heat, metals, lumber and other material supplies, as it is on the air we breathe, and, if it is to endure, we must quickly recognize that the utilization of these necessities must be based upon the greatest economy compatible with effectiveness.

Reared in the midst of national abundance, the idea has become a matter of common expression that when our present resources are gone "something else will be found to take their place," or that because we have not as yet suffered for the want of any of them, the time will never come when the nation will suffer in consequence of our past and present prodigality. But whatever may be the advances of applied science, the resources that nature supplies will always be needed.

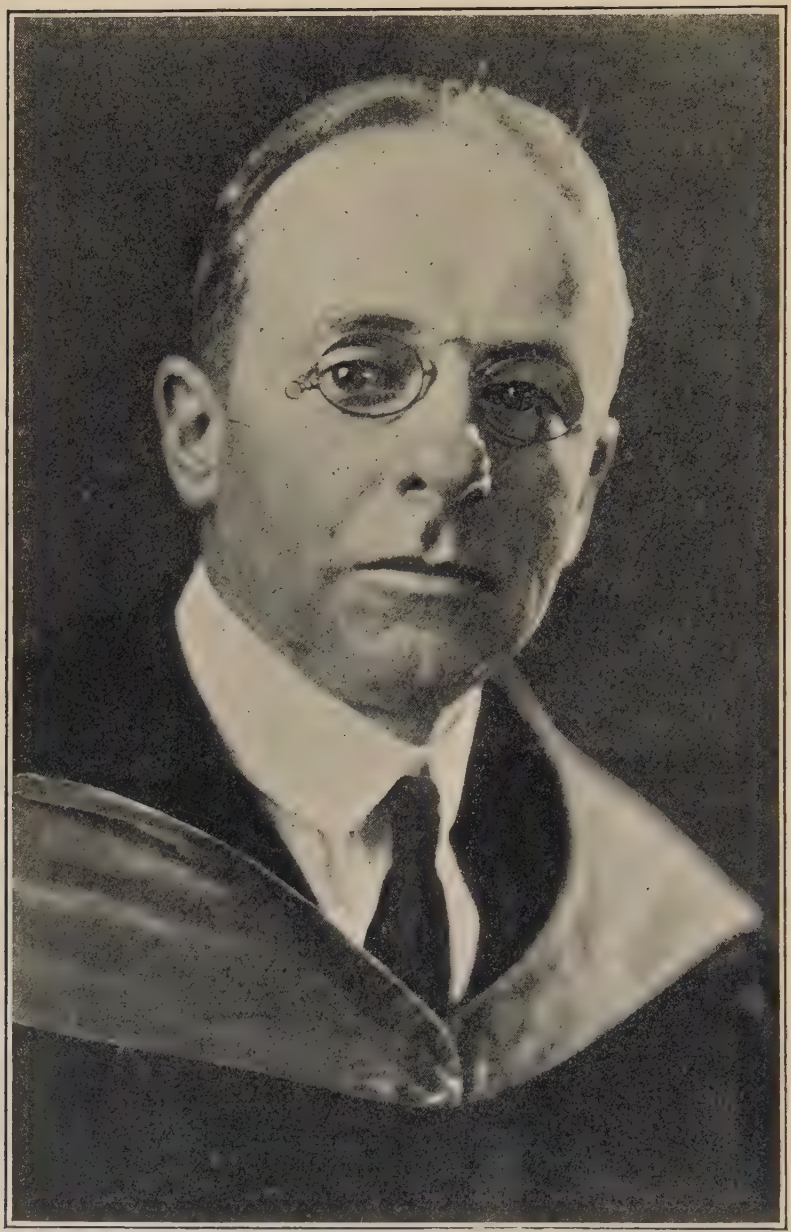
The natural wealth that we have inherited from the past is far from inexhaustible, and for this generation to pass away leaving a depleted heritage for those to come, with which to maintain and advance the civilization that we have here developed, would be a folly and a grievous iniquity.

Much that is called development is really destructive exploitation; much that we call production is really consumption; much that we call utilization is merely the sacrifice for small immediate profits of things that will be badly needed in the future. Nature has been so lavish with us that we have not felt the necessity of looking at these facts in their true light, but our nation and our civilization must have a future as well as a past.

It seems, therefore, to be an important duty of scientific men to disseminate information and instruction as to the real condition of our natural resources; to warn the nation where danger of exhaustion lies, and in the light of the best scientific and practical knowledge that we now possess, and through new researches directed to this end, to teach the ways in which our resources may best be maintained. These great economic problems are so involved with industrial, financial and political questions that little direct influence can be exerted without a long educational campaign. This will in time bear fruit, but the longer the time that will be required, the more important is an immediate beginning. Exact scientific knowledge alone can guide in this large field, but even science can not take care of industrial waste. Such correction can be made only by an enlightened moral sense.

THE EXECUTIVE COMMITTEE ON NATURAL RESOURCES

At the instance of the National Academy of Sciences, a committee of that body, and similar committees appointed by the American Association for the Advancement of Science and the National Research Council have held two meetings at the American Museum of Natural History in New



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JAMES ROWLAND ANGELL

Installed on June 22 as President of Yale University. Dr. Angell has been professor of psychology and dean of the faculties in the University of Chicago. During the past two years he has served successively as chairman of the National Research Council and president of the Carnegie Corporation

York City, to consider the status, utilization and protection of our natural resources. This joint board, which has been authorized to assume the name of the Executive Committee on Natural Resources, plans to promote the scientifically directed effort and education for the most efficient and advantageous use of our natural resources.

The committee plans the appointment of a paid executive and the necessary clerical force, with an office in Washington. Immediate steps will be taken to secure the cooperation of as many as possible of the educational and scientific institutions of the country. The committee will not duplicate the work of any existing organization; its purpose is to help them in securing better support. In the matter of correcting and furthering legislation that may bear on the subject of our natural resources, the committee expects to provide the facts and information and furnish a broad scientific basis for State and Federal action, keeping free from specific legislative problems.

This Executive Committee on Natural Resources lays claim to public confidence, as it is composed of scientific men of standing, representing the leading scientific organizations of the country. It is hoped that among the great body of patriotic and public-spirited citizens, there will be many to join in ensuring the initiation and maintenance of the work of the committee by their moral and financial support and encouragement, or by personal work for its success.

The following is the present membership of the committee:

Representing the National Academy of Sciences

John C. Merriam, President, the Carnegie Institution of Washington; John M. Clarke, Director, New York State Museum; J. McKeen Cattell, Editor, *The Science Press.*

Representing the National Research Council

John C. Merriam, John M. Clarke, J. McKeen Cattell, Vernon Kellogg, Secretary, National Research Council; C. E. McClung, Director, Zoological Laboratory, University of Pennsylvania.

Representing the American Association for the Advancement of Science

John C. Merriam, Henry S. Graves, Former Chief, U. S. Forest Service; Isaiah Bowman, Director, American Geographical Society; Barrington Moore, President, American Ecological Society; V. E. Shelford, Professor of Zoology, University of Illinois.

Chairman, John C. Merriam.

Vice-chairman, John M. Clarke.

Secretary, Albert L. Barrows, National Research Council, 1701 Massachusetts Avenue, Washington, D. C.

Assistant Secretary, Willard G. Van Name, American Museum of Natural History, New York, N. Y.

MME. CURIE'S VISIT TO THE UNITED STATES

The events arranged in honor of Mme. Curie have been fully reported, but it may be desirable to place them in consecutive order for permanent record.

Mme. Curie first visited Smith and Vassar colleges. On May 17 she was given a luncheon in New York by the American Chemical Society, the American Electrochemical Society, the Chemists Club and American sections of the Société de Chimie industrielle and the Society of Chemical Industry. In the evening a reception in honor of Mme. Curie was given at the American Museum of Natural History by the New York Academy of Sciences and the New York Mineralogical Club.

On Wednesday afternoon the American Association of University Women welcomed Madame Curie in Carnegie Hall. Addresses were made by Dr. Florence Sabin, professor of histology at the Johns Hopkins University, and Dr. Alice Hamilton, of the Harvard Medical School. President Pendleton, of Wellesley College, announced the award to Mme. Curie of the special Ellen Richards Research Prize of $2,000. On Thursday

PRESIDENT AND MRS. HARDING WITH MME. CURIE AND HER DAUGHTERS AT THE WHITE HOUSE

evening, at a dinner given in her honor by the National Institute of Social Science, the gold medal of the society was presented to her.

The gram of radium valued at $120,000, a gift from the women of America, was presented to Mme. Curie by President Harding on May 20. M. Jusserand, the French Ambassador, made a brief introduction. After the presentation Mme. Curie responded as follows:

I can not express to you the emotion which fills my heart in this moment. You, the chief of this great Republic of the United States, honor me as no woman has ever been honored in America before. The destiny of a nation whose women can do what your countrywomen do to-day through you, Mr. President, is sure and safe. It gives me confidence in the destiny of democracy.

I accept this rare gift, Mr. President, with the hope that I may make it serve mankind. I thank your countrywomen in the name of France. I thank them in the name of humanity which we all wish so much to make happier. I love you all, my American friends, very much.

In the evening at a meeting held under the auspices of the U. S. National Museum, Miss Julia Lathrop extended to Mme. Curie greetings, and Dr. Robert A. Millikan, of the University of Chicago, gave an address on radium, describing the researches that led to its isolation by Mme. Curie. On the following day Mme. Curie set in motion the machinery of the new low temperature laboratory of the Bureau of Mines, which is dedicated to her.

The following week Mme. Curie visited the laboratories at Pittsburgh where was refined the gram of radium presented to her.

Subsequently Mme. Curie visited the Grand Canyon and Yellowstone Park. Returning to Chicago, the Wolcott Gibbs medal was conferred on her by the Chicago Section of the American Chemical Society, and she was entertained by the University of Chicago and by the Associated Women's Organizations. After a visit to Niagara Falls and a reception at Buffalo, she proceeded to Boston, where among other functions a dinner was given in her honor by the American Academy of Arts and Sciences. Mme. Curie then planned to visit New Haven to be present at the installation of President Angell on June 22. She expected to sail with her daughters for France on June 25.

EXCHANGE OF PROFESSORS OF ENGINEERING BETWEEN AMERICAN AND FRENCH UNIVERSITIES

There has been for some time a regular annual exchange of professors between individual universities in France and America in regular academic fields, such as literature, history, law, fine arts, economics, etc., but no such exchange in engineering or applied science. These subjects are taught in France under special faculties, not included in existing exchanges with America. Furthermore, the French methods of teaching these subjects are unlike our American methods, for various reasons, based on the history, traditions and sociology of the two countries. The war showed the importance of engineering in production and distribution, and the many ties of friendship which bind us to France depend in various ways upon applied science. It should therefore, be to the mutual advantage of France and America to become better acquainted with each other's ideals and viewpoints, in the study and in the teaching of these subjects.

With these purposes in mind, the late Dr. R. C. Maclaurin, in 1919, as president of the Massachusetts Institute of Technology, consulted the presidents of six universities on or near the Atlantic seaboard, as to whether they deemed it desirable to coöperate in a joint exchange of professors with France, on a plan definitely outlined. Their replies being favorable to the project, a committee was appointed, with one member from each of the seven institu-

tions, to report on the plan, and on methods of carrying it into effect. The committee met in December, 1919, and ratified the coöperative plan with some few modifications. The present president of the committee is Director Russell H. Chittenden, of Yale University, and its secretary Dean J. B. Whitehead of the Johns Hopkins University.

Since the Institute of International Education, in New York, concerns itself with the interchange of college students and teachers from all parts of the world, the committee requested the director, Dr. Stephen P. Duggan, to undertake the negotiations between the committee and the French university administration. The French administration responded cordially to the offer for the annual exchange of a professor. The French have selected, for their first representative, Professor J. Cavalier, rector of the University of Toulouse, a well-known authority on metallurgical chemistry, to come to America this fall, and to divide his time during the ensuing academic year, among the seven coöperating institutions, namely, Columbia, Cornell, Harvard, Johns Hopkins, the Massachusetts Institute of Technology, Pennsylvania and Yale.

The American universities have selected as their outgoing representative for the same first year (1921-22), Dr. A. E. Kennelly, professor of electrical engineering at Harvard University and the Massachusetts Institute of Technology.

SCIENTIFIC ITEMS

We record with regret the death of Edward Bennett Rosa, chief physicist of the Bureau of Standards and of Abbott Thayer, the distinguished artist. Readers of this journal will remember Dr. Rosa's recent article on the economic importance of the scientific work of the government and Mr. Thayer's articles on protective coloration.

The Royal Society has elected as foreign members Dr. Albert Calmette, of the Pasteur Institute; Dr. Henri Deslandres, of the Paris Observatory; Professor Albert Einstein, of the University of Berlin; Professor Albin Haller, of the University of Paris; Professor E. B. Wilson, of Columbia University, and Professor P. Zeeman, of the University of Amsterdam.

Professor Albert Einstein sailed for Liverpool on the *Celtic* on May 30. He has since delivered the Adamson lecture of the University of Manchester and given lectures at King's College, London, and other institutions.

A commission of five engineers has been appointed to visit England in June to present the John Fritz medal to Sir John Hadfield, in recognition of his scientific research work. The members of the commission are as follows: Dr. Ira N. Hollis, president of Worcester Polytechnic Institute; Charles T. Main, of Boston, representing the American Society of Civil Engineers; Col. Arthur S. Dwight, of New York, representing the American Institute of Mining and Metallurgical Engineers; Ambrose Swasey, of Cleveland, of the John Fritz medal award board and the American Society of Mechanical Engineers, and Dr. F. B. Jewett, of New York, of the American Institute of Electrical Engineers.

THE SCIENTIFIC MONTHLY

AUGUST, 1921

THE SCIENTIFIC CAREER FOR WOMEN[1]

By DR. SIMON FLEXNER

THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH

MAY 18 of this year witnessed a notable public event. A gathering of several thousand persons, for the most part college women, filling throughout the huge auditorium of Carnegie Hall in New York, assembled to do honor to a woman who had added a great new fact to science, and that audience was only one of the many that have assembled during the past few weeks for the same purpose. Following as it did so closely on the great war and the homage being paid to military and diplomatic leaders of the victorious nations, the occasion stands forth by contrast as signalling a new and precious order in which the triumphs of the intellect, in this instance as embodied in Madame Curie, received a merited recognition and reward. The statement is often heard that the achievements which society most honors, even in times of peace, are not the laborious ones of learning, but rather the more spectacular ones of the military profession; and it is just this perversion of values which now perhaps more than in any previous period is so disheartening. And yet the event just mentioned by no means lends support to this common point of view, but may rather be looked upon as affording a new hope and inspiring a new courage with which to meet the immeasurably important problems of society now pending.

It is perhaps also permissible to find significance in the fact that the recipient of the high honors now being conferred everywhere in this country on the discoverer of radium is a woman. In view of the discovery itself and the impetus given by it to physical, chemical, and even biological research, it may seem idle to ask the question I have so often heard asked whether there exists a scientific career for women. But there are without doubt many people who will insist that one such achievement, great as it is, can not be taken as setting aside for once and all speculation on the subject. They may continue to doubt.

[1] An address given at the commencement exercises of Bryn Mawr College, on June 2, 1921.

None the less one must admit that Madame Curie's example is a great and encouraging one for women.

The scientific career is not under all circumstances one thing. Its opportunities adapt themselves rather to different times and different types of mind. One of Leonardo da Vinci's aphorisms was that truth is always the daughter of her period. We readily distinguish two main kinds of scientific achievement or discovery so called—one of which is the outgrowth or the efflorescence of a line of investigation dealing with things predictable. The result accomplished may be new and important, but having been foreshadowed by the march of scientific events, it lacks essential novelty. For this kind of discovery, knowledge—often deep and precise—and method, but not the highest talent, are demanded. The other partakes of the accidental rather than the incidental; it never comes as a direct, but rather as an unexpected result or side issue to some line of inquiry, as something for which there is no precedent, and hence it may be easily overlooked. Discovery in this field is more certainly the mark of that individuality to which the designation genius has been applied. Perhaps the qualities which distinguish it may be aptly defined under the phrase invented by Pasteur of the "prepared mind," that is, the mind so gifted with imaginative insight and so fortified by accurate training as to be alert to perceive and quick to seize upon the novel and essential, which is turned at once to unexpected uses. It has been well said that "the discovery which has been pointed to by theory is always one of profound interest and importance, but it is usually the close and crown of a long and fruitful period; whereas the discovery which comes as a puzzled surprise usually marks a fresh epoch and opens a new chapter of science." [1]

The two kinds of achievement are discernible in the work of more than one great investigator. Thus Pasteur's laborious and ingenious studies which led first to the overthrow of the doctrine of the spontaneous generation of life, and then by way of the all important demonstration of the biological nature of the processes of fermentation and putrefaction to the secure founding of the germ origin of infectious disease, may be considered as having been previously foreshadowed; while his epochal discoveries in crystallography and in the domain of immunity were as clearly the harvests of the exceptionally brilliant and prepared mind.

The history of science contains not a few instances in which the line of investigation being carried on at a particular juncture by the master exerts a strong, often indelible and permanently directive impression upon a pupil. Thus, for example, the life work of Professor Theodore Richards in this country, which has corrected and re-

[1] Lodge, Oliver, Becquerel Memorial Lecture, Journal of the Chemical Society. Transactions 1912, V. 101, II, p. 2005.

established the atomic weights of certain elements and for which he has received the highest honors in science, was begun under his first professor of chemistry. In like manner Pasteur became imbued with his master Delafosse's enthusiasm for crystal structure, considered with reference to the relation of atoms to the rotatory power upon a beam of polarized light. Hence when Pasteur obtained his first position of "preparateur" to the professor of chemistry, he set himself the task of studying crystal forms and by good chance chose the tartrates in which the phenomena he was seeking appear in the simplest form. Had he chosen other crystals, he would have had to search much longer to find the particular appearances so clear in them, but that in the end he would have succeeded may be assumed. What was constantly in Pasteur's mind at this early period was the correlation between a particular crystalline form called hemihedrism and rotatory power. This relation is determined by little faces on one-half of the edges of the crystals, the existence of which had already been noted by two chemists, the one a conscientious observer without inspiration, or as the French say *sans flamme*, and the other preoccupied with a theory which he endeavored to fit to all the facts which his studies revealed. Both thus failed to understand their significance.

Pasteur's discovery, although strictly speaking a discovery in chemistry, later had its percussion through the entire realm of science in a manner so profound that to-day, seventy years after the event, its reverberations have not yet ceased. His biographer has described it as follows:

"Pasteur noticed that the crystals of tartaric acid and the tartrates had little faces on one-half of their edges or similar angles (hemihedrism). When the crystal was placed before a glass the image that appeared could not be superposed; the comparison of the two hands was applicable to it. Pasteur thought that this aspect of the crystal might be an index of what existed within the molecules, a dissymmetry of form corresponding with molecular dissymmetry. Therefore, he reasoned the deviation to the right of the plane of polarization produced by tartrate and the optical neutrality of the paratartrate would be explained by a structural law. The first of these conclusions was confirmed, but when he came to examine the crystals of paratartrate hoping to find none of them with faces, he experienced a keen disappointment. The paratartrate was also hemihedral, but the faces of some of the crystals were inclined to the right, and those of others to the left. It then occurred to Pasteur to take up these crystals one by one and sort them carefully, putting on one side those which turned to the left, and on the other those which turned to the right. He thought that by obtaining their respective solutions in the polarizing apparatus, the two contrary hemihedral forms would give two contrary

deviations; and then by mixing together an equal number of each kind, the resulting solution would be neutral and have no action upon light. With anxious and beating heart he proceeded to the polarizing apparatus and exclaimed 'I have it.' His excitement was such that he could not look at the apparatus again; he rushed out of the laboratory, not unlike Archimedes. In the passage he met a curator and embracing him dragged him out with him into the Luxembourg gardens to explain his discovery. Many confidences had been whispered under the shade of the tall trees of those avenues, but never was there greater or more exuberant joy on a young man's face. He foresaw all the consequences of the discovery.* * * *"[2]

In like manner there can be no doubt that the discovery by Pasteur in 1880 of the artificial immunity to fowl cholera, which opened up to exploitation the wide and varied field of immunity in medicine and which is to-day one of the main achievements of medical science and is holding out still greater promises of progress in the control of disease in the future, came not as a direct incident, but rather as an accidental circumstance to the experiments on infection being pursued.

So it was also with the discovery of spontaneous radioactivity by Becquerel, to which are directly traceable the discovery of radium, and the superlative and successful efforts now being made to solve the age-long problem of the atomic constitution of matter; while Madame Curie's discovery of radium itself was not the result of a momentary inspiration on her part, but rather the consummation of a labor extending over many years, begun under conditions of great hardship and continued through obstacles and discouragements which only the great in spirit surmount.

I shall not tarry on the threshold of the story to repeat to you the details of the preliminary steps in the great career of Madame Curie, during which she did what was virtually the menial service of the Sorbonne, in order to gain the pittance of support which enabled her to enter on her scientific training. But in the end her ability was detected and she was placed in the laboratory to conduct an investigation leading to a thesis, and as it happened, under the young instructor who afterwards became her husband.

The story begins about 1860, from which time on many observations had been made on the passage of electricity through tubes from which nearly all the air had been pumped. These studies led in 1879 to the discovery of the cathode rays of Sir William Crookes and in 1895 to the discovery of X-rays by Röntgen. A year later, or to be exact, on March 7, 1896, Becquerel, who was studying the general behavior of phosphorescent bodies, examined uranium and its compounds, and discovered that these substances gave off rays which re-

[2] Vallery-Radot, The Life of Pasteur, Eng. Trans. Vol. I, p. 50.

sembled the X-rays in their action on photographic plates. He also made the extremely important observation that the rays "ionized" the air about them, or converted it from an insulator to a conductor of electricity. A gold-leaf electroscope, which had been previously charged with electricity so that its two leaves diverged, was discharged, with the consequent collapse of its leaves as soon as uranium was brought near it.

The comparative ease and rapidity and metrical character of this method of examination induced Madame Curie to take as the subject of her doctorial thesis the measurement of the radioactive powers of an immense number of minerals, and so led her gradually to one of the most brilliant and striking discoveries of modern times, the whole representing a new epoch in our knowledge of atoms and therefore in physico-chemical science.[3] Her initial momentous observation related to the mineral pitchblende from which uranium is extracted, and which she found to be four or five times as radioactive as uranium itself. There was, of course, but one possible conclusion: the mineral contained another active element more powerful than uranium. At this point her husband joined in the quest and the mineral was converted into fractions, each of which was tested electroscopically. The bismuth fraction showed the presence of a powerful radioactive substance finally separated, and in honor of Madame Curie's native country called polonium; but it was the barium fraction which was most active and which finally yielded a salt of the new element called radium. Thus it was in 1902, or after four years of arduous and inspiring work, that the researches leading to the doctor's degree but also unlocking a new door in physics were brought to a temporary conclusion, and it was not until 1910, as you know, that Madame Curie actually obtained the element radium in a pure state. It is of some interest to recall that the radium salt proved 2,500,000 times as active as the uranium, the point from which her studies started.

Honors flowed in upon the discoverer. In 1903, she shared with Becquerel and her husband the Nobel prize. Then in 1911, after the isolation of pure radium, she was a second time awarded that great prize and in the words of the President of the Swedish Academy, was the first laureate to be awarded this distinction twice as "a proof of the importance which our Academy attaches to your discoveries * * *." And yet, because she was a woman, the French Institute declined to elect her to membership and the five French academies voted in favor of upholding "an immutable tradition against the election of women which it seemed eminently wise to respect."

Great discoveries never stand isolated and hence it frequently hap-

[3] Lodge, Oliver, op. cit.

pens that their main effect is to set into motion as by-products, secondary or new lines of research, the significance of which often eclipses the great discovery from which they took origin. Hence to-day it is especially in atomic physics and then in biology that the fructifying influence of the investigations in the field of radioactivity is noteworthy. It has happened that new and unimagined forces have been released suddenly for experiment and placed in the hands of the physicist and the biologist. I am not capable of giving an account of the latest experiments on atomic constitution which are being conducted with radium, and I stand filled with wonder and admiration as I read that the rapidity of the α-particle or helium atom derived from radium is about 20,000 times the speed of a rifle bullet, and that the energy of this motion is such that an ounce of helium moving with the speed of the α-particle is equivalent to 10,000 tons of solid shot projected with the velocity of 1000 meters per second. After having been stunned by this statement, I can well imagine that the charged particle is able to penetrate deeply into the structure of all atoms, built up as they are now believed to be on a plan similar to that of the solar system with a central sun or nucleus, and a system of planets in form of negative electrons, and to pass through as many as 500,000 of them before being deflected and turned back, and thus made to divulge the secrets of the electric fields near the center or nucleus of the atom.

But I may be somewhat better able to explain the present status of biological research being carried out with radioactive substances derived both from X-ray and from radium. The studies are proceeding in two directions: the one being of theoretical and the other of practical nature. The latter excite the greater interest because they are already rendering a highly useful service, as in the treatment of a certain class of cancers and in reducing excessive amounts of lymphatic tissue, even including recently the ubiquitous enlarged tonsils and adenoids. And yet, the former may in the end be of surpassing value in that they will serve to explain the manner in which radioactivity brings about the biological effects noted, and the means by which those which are desirable and useful may be intensified and those which are undesirable, because harmful, may be minimized or avoided altogether. Already we have learned that the radiations act quite directly on the lymphoid organs and, according to the amount or dosage employed, either stimulate to over-activity or bring about destruction; while the action on cancerous tissue is more indirect and bound up, in part at least, with the impression made upon the lymphatic system. But what I especially desire to emphasize is the connection which this class of investigations has established between the physicist and the biologist. It happens that neither alone can compass the entire field; the one is

too little a physicist, the other too little a biologist in order to manage on the one hand the rays and on the other the tissues. Together they make a working team, and already a new division of research in biophysics is beginning to appear to herald that co-operation in scientific research which is to-day one of the necessities as it is the harbinger of progress.

It should now be apparent how impossible it is for mere accident to yield a discovery in science. Whether the investigator move in the lower or the upper realm of experiment and observation, there are demanded as a minimum, knowledge of fact and familiarity with method, with which not even the most fortunately circumstanced are naturally endowed. Environment and possibly heredity also play parts, sometimes highly important parts, in giving the impulsion which leads into scientific careers and accomplishment. Moreover it is a mistaken notion to suppose that the scientific intelligence can only be and always is trained in school or college as ordinarily defined. The history of science indeed contains illuminating pages recounting the successes of men without any real formal education who have surmounted all difficulties and written their names large in its story. Such a man was Michael Faraday, of whom it has been said that of all the men who have spent their lives in the search for experimental discoveries, no one has ever approached him in the number, variety, or the importance of the new facts disclosed by his labors; and yet he was led into the pursuit of science by reading the books which passed through his hands while he was a bookbinder's apprentice.

Hitherto it has been men rather than women who have chosen the scientific career, and up to now the shining names on the banner of science are those of men and not of women. It could not have been otherwise; but now that the doors of opportunity have been thrown widely open to women, one may expect that many more will pass their portals and enter upon the career of science. Already they are feeling its lure and perceiving their aptitudes. But the lesson can not be enforced too emphatically that whether science is entered by the front door of the college or by the back door of the amateur or apprentice, in the end the material and means of science must be mastered if the votary aspires to enter paths never trodden before. To acquire that mastery to-day is no small undertaking, since the subject matter of the sciences is so voluminous and the methods often so intricate and precise. But there is nothing in my opinion in either which the trained intelligence can not grasp and the trained senses execute.

I do not recognize a line of demarcation between the sciences which men on the one hand and women on the other should choose as a career. With women as with men what should count are taste and aptitude and opportunity. It is common experience to find that a man

is directed or diverted into a given scientific field by accidental circumstances: a book falling into his hands at a critical moment; a particularly inspiring teacher who, like radium, transmutes his pupils as that does the elements; a region favorable say to geological study; a parent or other person with whom the impressionable child chances to be thrown. Once fairly launched on a career, the native ability determines the rest, just what particular road is followed and how far the traveller is carried along the road.

Even earlier influences may come to play a deciding part in directing the will and bent of the child. It does not take special insight to discern the differences in the intellectual atmosphere surrounding boys and girls in the home. While the girl is complacently occupied with dolls and miniature dressmaking and millinery, the boy's imagination is being excited by mechanical toys which his aroused interest impels him to destroy, in order that the inner mechanism may be laid bare. This is the period at which a youthful Galileo and Newton will construct windmills and water clocks, and a future Herschel, aided perhaps by another sister Carolin, will fashion some sort of optical device, the forerunner of his first telescope.

Then also custom and habit will determine that the father himself on science bent will endeavor to communicate his taste to his son rather than to his daughter. It took three generations of the Becquerel family, all concerned with the study of light phenomena, to produce the discoverer of spontaneous radioactivity. Charles Darwin's son and now his grandson are pursuing at Cambridge with distinction the related fields of mathematical astronomy and mathematical physics. Perkins, the discoverer when only seventeen years of age of the aniline dyes, has been followed by a son, the eminent professor of chemistry at Oxford; and father and son of the Bragg family have recently shared the Nobel prize for discoveries in physics.

The examples might be multiplied in which because of custom the boy, but not the girl, has been subjected to influences extending over many years calculated to prepare or to lead him, if only insensibly, into the paths of science. Moreover, the boy has other advantages to guide and spur him on: once launched on a scientific pursuit, he looks forward to a life's career and indulges the hope, if not the expectation, of being attended by some good woman. Now women have not yet been offered anything approaching a like opportunity to that put before men. The scientific career means too often for them, if consistently pursued, the denial of domestic companionships and compensations which men easily win and enjoy. In how far this condition alone will operate to bar women from the higher pursuits and greater rewards of a scientific career only experience can show. But as one who would write himself down a lover of opportunity for women, I wish to ex-

press the hope that the difficulty may not prove insurmountable. Already in this country and in two fields of which I have personal knowledge, Doctor Florence Sabin of the Johns Hopkins Medical School and Doctor Louise Pearce of the Rockefeller Institute for Medical Research have made themselves authorities in their respective branches of medical science. The latter has recently carried out a difficult mission to the Belgian Congo in connection with African sleeping sickness, such as formerly would have been entrusted to a man.

A last word. I have not spoken of the rewards of the scientific career. As with other intellectual pursuits, they are to be reckoned only partly in the coin of the country. Science is now so far developed in the United States that in college, research institution, or industry a competence can readily enough be found. In the end the greater reward will be an inner satisfaction and happiness arising out of a conscious mastery of a field of human endeavor. But for this there must be a real mastery such as comes not easily but only after a period of years and as a result of a seriousness of purpose and a concentration of effort which alone devotion to a high cause will insure.

THE MESSAGE OF THE ZEITGEIST

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THACKERAY wished he could have been Shakespeare's bootblack, and many English men of letters rank the Elizabethan above the Victorian age. Classicists have often wished they had lived in the day of Plato or Caesar, as if their age were superior to our own. F. W. Robertson said he would give all his life in exchange for an hour's talk with Jesus just after the Sermon on the Mount. Ruskin, William Morris and their group, since we can not turn the wheels of time backward, would reconstruct our own industrial and social system on the pattern of the ancient guilds. For good Catholics, the apical blossom of the Tree of Life was found in the apostolic, patristic, or scholastic period, and all that has happened in the world since is of really far less import. For Max Müller, the life of the primitive Aryan; for Schliemann, that of the Homeric age; for Tacitus, the ancient Germans, were nearest the ideal, while for Plato the golden age was in the lost Atlantis and belonged to another era.

Christianity first in its doctrine of a millennium began the new fashion of looking to the future for Utopia when we seek to escape the pressure of present reality, and to this tendency evolution has now given a great impulse, as seen in the writings of Bellamy, H. G. Wells, Pataud and Pouget, C. W. Woodbridge, Chapman, Cramm, Howe, Tangent and many other portrayers of the great and glorious things yet to come on earth or yet possible. For those who abandon themselves to such reveries, the present seems preparatory for something greater, if not again, a trifle mean compared with Altruria, Equitania, Sub-Coelum or even Meccania. During and since the war there has been a great revival of interest in what might, could, would, or should be, often in some vague or obscure place, perhaps at a time no less indeterminate, and sometimes our El Dorados have been projected to the center of the earth or to another planet—Mars—Saturn, etc.

Now, my thesis is that all such fugues from actuality and what Desjardin made supreme, *viz., le devoir présent,* are now as never before in history, weak and cowardly, flights from the duty of the hour, wasteful of precious energy, and, perhaps worst of all, they are a symptom of low morale, personal or civic, or both. True greatness consists solely in seeing everything, past, future or afar, in terms of the Here and Now, or in the power of "presentification."

The equivalent of everything that ever was, is, or can be made to happen, is not far off or in some other life, age, or place, but within or about us. Creative processes take changing forms, but the energy that impels them is identical with that which started cosmic evolution. All the Hebrew prophets did and said, we now know was inspired by the needs of the hour in which they lived, and they never strove to foretell the far future. Our time is just as ripe for a true Messiah as when the Star of Bethlehem appeared, and a new dispensation is just as needed and just as possible as when the Baptist heralded the advent of the greatest of all "presentifiers." Now, when all human institutions so slowly and laboriously evolved are impugned, every consensus challenged, every creed flouted, as much as and perhaps even more than by the ancient Sophists, the call comes to us as it did to Plato (all of whose work was inspired by the need he felt of going back to first principles) to explore, test, and if necessary reconstruct the very bases of conviction, for all open questions are new opportunities. Old beacon lights have shifted or gone out. Some of the issues we lately thought to be minor have taken on cosmic dimensions. We are all "up against" questions too big for us so that there is everywhere a sense of insufficiency which is too deep to be fully deployed in the narrow field of consciousness. Hence there is a new discontent with old leaders, standards, criteria, methods and values, and a demand everywhere for new ones, a realization that mankind must now reorient itself and take its bearings from the eternal stars and sail no longer into the unknown future by the dead reckonings of the past. We must find or make and ascend a new outlook tower high enough to command the whole earth and its history, and become familiar with the perspective and other phenomena of altitude, although this is perhaps the hardest of all things for our distracted, analytic, and specialist-ridden stage of culture.

In a word, the world is sick and needs again a great physician for its soul just as it does for its body (one-third of our youth being unfit to fight). Its distempers, however, we hope may prove to be those of youth and not of old age, but even if the latter, they are ominous for the maturity of the race. Many specialists have diagnosed and prescribed but they all deal with symptoms, and the real nature and true cause of the disease still baffle us. It may well seem preposterous to the whole guild of doctors for a layman in everything, whose only advantage is his aloofness from all their works and ways, to suggest a deeper cause demanding a more radical therapy. In what follows, however, I shall venture to attempt nothing less than this. Underlying almost everything else is the fact that man has now filled the whole earth and that it will soon become even too full of his species. The human population has in nearly every nook of the globe been increasing in the last few generations at a prodigious rate, and its pressure upon the means of subsistence is already in many regions more acute than even

Malthus foresaw. In this country almost within the memory of men now living, not only the Pacific coast but even the great Mississippi valley has been filled with a teeming and enterprising population. In 1890 some of the great powers doubted the advantage of extensive colonies in remote regions, but since the great land scramble in the decade that followed, about every part of the inhabitable earth has been appropriated, explored, and is now being exploited. All Africa is apportioned, and not only Australia but Madagascar, Borneo, New Guinea, and all the smallest of islands opened up so that there are not only no new continents but practically no new acres to be discovered. The great era of diffusion and tenancy is practically ended. Man has not only taken possession of every room but of every closet of his terrestrial habitation.

In this expansion he has been wasteful of material resources to a degree so prodigal that we can now approximately date the exhaustion of many of them. Prospecting has been so extensive and careful that there will probably be no more great new finds of gold, silver, diamonds, coal, natural gas, etc., like those of the past, and the lure and glamor of great new openings thus made is already abating; while the acreage that once yielded bumper crops without fertilization is losing its spontaneous fertility.

The moral of all these trite facts is that henceforth the progress of the world must depend upon quality, not quantity; trust more to nurture and less to nature; realize that it can reap only where and what it has sown; must row where it has hitherto drifted with the current. This country especially has grown to be the richest and greatest in the world by its natural resources, but it must henceforth not only conserve but laboriously cultivate. We have found that hereafter we must make and can not expect to find our ways. And no less important is the development of our human quality.

In the geologic history of the globe the great epochs have been marked by the alternation of two periods: first, that of the emergence of vast areas of land from the primeval sea and its tenancy by species which populated it from the ocean, adjusted themselves to terrestrial conditions, and found a table spread for them so rich that they multiplied, varied, and spread with great rapidity. Then the tides turned and there were long periods of submergence and reduction of land areas during which many forms that had established themselves upon terra firma went back to their first love, the sea, like whales and dolphins; dwindled to insignificant size; or became extinct, like the great saurians, because they could not adapt to a new habitat. What makes our age great beyond all historic comparisons is that it has seen within the last few years the high tide of man's great processional over the earth and also the beginning of the recessional ebb when the world must have a new type of both men and measures or else revert to a more primitive stage of

civilization. Already we see about us many alarming signs of regression. The great war itself, which marked so signally the turn of this all-dominating tide in human affairs, was only the inauguration of the colossal conflict between the old forces that expanded and the new ones now in the ascendant that would redirect the progress of man by adjusting to the new turn of fate.

If our planet had doubled in size while it has doubled in population; if a vast, rich, new continent had just been discovered, as in 1492, or emerged from the sea; if the population of Europe had remained what it was in the days of Napoleon; if man's wants had not increased or the standards of living risen or surplus products and foreign markets had remained unknown, and there had been no surplus population anywhere, Germany would never have had her mad dream of subjecting Europe, for the world war marked the first impact and repercussion of the great current of expansion, which had behind it the whole momentum of cosmic evolution upon material limitations. Thus man has in a sense outgrown his world, so that it is now too small for him. From now on development must be intensive rather than extensive, and inward as well as outward.

When a ship is wrecked on a savage island, passengers and crew are thrown back to primitive conditions and adapt to a new environment and adopt new leaders, and often reverse all conventional discriminations; and Bolshevism is only an ostensive paradigm of what the *Zeitgeist* is doing, only more slowly and comprehensively, for the world, which is being thrown back to first principles, and finding these to be no longer political but chiefly economic and psychological so that even its past history has to be rewritten with a new perspective.

If the wealth of any land were equally divided, everybody would be poor, not rich, and there is not wealth enough in the world to satisfy one one-hundredth of the present demand for it. As civilization advances, it costs not only more money, but more time and effort to keep people happy. Thus there is a rapidly growing excess of demand for pleasure over the supply, so that the volume of discontent is constantly mounting. This life, which is all man now really believes in or cares for, can not begin to give what he asks of it. The average individual now never thinks of the far future of the world or even of his own posterity for more than a generation or two, but wants all that is coming to him now and here, and uses every means in his power (fair and sometimes foul) to get it. Thus he plunges on toward the bankruptcy of his hopes in their present form and sagacious minds are now realizing that humanity can never be satisfied save by restricting its desires or by transforming and re-directing its aspirations to more attainable goals; or, in more technical language, by finding more internal surrogates for their gratification.

This means nothing less than that the world is now squarely up against the problem of getting a deeper knowledge of human nature and finding more effective ways of guiding it or of refitting Teufelsdrock's institutional clothes to his person, if not getting him a new suit. We must not forget that while our industrial system is less than two hundred years old and even our political institutions go back only a few thousand years, man is at least a hundred thousand years old, and that we must readjust to all better knowledge of him, just as we do to all the newly discovered laws of nature. Thus as man has reached and rebounded from his geographic and other limits, his ideals of material prosperity have also impinged upon adamantine limits, and the current of his psychic evolution must now finally make a new way in another direction. Just as there are now countless individuals who should never have been born and who could in no way so benefit the world as by taking themselves out of it (but who will never do it, so that society and industry must find ways of utilizing them as best they can, trusting the slow processes of evolution to better the human stock), so there are innumerable spurious hopes, ambitions and aspirations which should never have arisen, but which we must learn to utilize and sublimate, striving slowly to subject opportunity to social and human aims.

Nature and Man—there is nothing else outside, above, or beyond these in the universe, and there never was or will be anywhere any item of creative or conservative energy or influence either in nature or mansoul that is not just as active here and now as it ever was or will be anywhere.

The way down the long scale from cortex to cord or even from man to mollusc is as broad as the way up is straight and narrow, and many there be that walk therein. The lowest sixth of the population of England, we are told, produce one-half of the rising generation, and infra-men breed a hundred times as fast as really eugenic super-men. The forces that make for human degeneration were never so many, so active, or so ominous, and nothing less than civilization itself is at stake. It has never entered into the heart of even pessimists to conceive what might happen if anarchy should prevail. But as Christianity came in to save the world when Rome and the ancient order fell, by proclaiming immortality, so now the idea of plasmal, which comes by better breeding, and of influential immortality, that saves by contributing new knowledge and power—these constitute our only hope of salvation. The promise is to those who seek, knock, ask, and is still open to the investigator, who is its true heir.

Man had a most insignificant origin—a finger-long worm with a withy spine; then a timid, tiny frugiverous creature for whom there was no safety save in trees. Then there was a long and doubtful struggle whether he or the great carnivora should be lords of creation

for he was few and his enemies many. But during all this time he was acquiring unprecedented power of docility and adaptation, and the evolutionary urge focussed on his species as its own chosen son. For ages, too, he quailed before creatures of his own imagination which he fancied real and potent, and only now is he beginning to realize that he is truly supreme in all the universe we know, and that there is nothing above or beyond him. Thus progress consists solely in the subjection of nature to man and of his own instincts to reason and his selfish interests to the common good, and man sees his destiny, which is to rule the world within and without by the power that comes from knowledge. He must go on learning to control where he has been controlled. This is his vocation as man. As the development of erectness and of the hand, which could grasp the club and impel the point of flint first made him man, so now science is both his organ of apprehension and his tool by which he must make his sovereignty complete, come fully into his kingdom and make his reign supreme. Thus, again, we see that research is his highest function. He is and always has been the investigator *par excellence*, and now he sees his calling and election more clearly, and in the new era which is upon us he has new and unprecedented motivation for mobilizing all his energies to make his title of conquisitor clear.

If the spirit of research be the Paraclete, the native breath and vital air of all true leaders in the world now being born, we ought to know more about it. What, then, is it? It is not sufficient to say it is creation in its most modern active stage, impelled by the primal impulse by which worlds evolved out of chaos, nebulae or any other mother-lye. This is true but trite. If any kind of superman is ever evolved, and the man of the present day is destined to become a missing link like the Java man, nurture must come to the aid of nature with every hebamic art that eugenics and education can supply, even though our remote posterity be as ashamed of having sprung from us as some still are of our simian ancestry. Curiosity, seen in all the higher forms of animal life, so strong in apes and so favored by their safe arboreal life, and which harks back to the original *fiat lux*, is surely one factor in the psychogenesis of the research urge. Strong as this noetic urge is, ambition, emulation and the desire to excel is surely another factor. Perhaps the hunting and collecting instinct made their contributions to it. Philanthropy or the desire to better the estate of man and to give him command of new resources is yet another element, and this has countless lower though always beneficent expressions in the impulse to alleviate suffering and in the amelioration of the tragedy in the grim struggle for survival. But the ultimate motivation of the investigator, often deeper than his consciousness, is the will for power to dominate nature, and to make man ever more completely ruler and master of the world within and without. As man is the highest and

best and as mind is the best thing in him, so research is the supreme function of mind, the true heir of the kingdom and of all the promises. Research specializes because it must divide in order to conquer. It makes such conditions for its experiments as can be controlled and excludes all others. We refine our methods and apparatus only in order to make such answers as we can extract from the memnonian lips of the sphinx more definite and explicit. Despite its baffling technique, science is, as Vähinger long ago so convincingly showed us, the quickest and easiest way of grasping the universe.

In view of all this we must regard nothing as quite so opportune or so true an expression of the Zeitgeist as the efforts to perfect the organization of the National Research Council in this country, the British Privy Council of Scientific and Industrial Research, and the international reorganization at Brussels to the same end. There are countless new problems in astronomy, geography, geology, archaeology, anthropology, economics, and in many other fields that can be solved only by wide co-operative methods, which often also require large funds, wise administration, systematic publication of results, and the spur, which pure science in a measure always lacks, of immediate utility, for every new discovery possible must be made serviceable.

It is inspiring to be authoritatively told that whereas fifteen years ago there were only four thousand individuals in this country who could be called investigators, there are now more than ten thousand who would be called such, and also that there are yet possible "finds," sometimes of great value, that can still be made even by amateurs and non-experts whom chance or locality favor, and that more can be recruited for this army of advance by questionnaire or correspondence methods. The prospector, placer-miner, still has his place in any comprehensive survey of research planning, and this work needs a consistorium of its own.

But we must not forget that the true spirit of research at its best can never be organized or administered and that to do so suggests simony, the sin of the purchase of the gift of the Spirit with money. Its very essence is freedom, and we can no more organize it than we can love, art, literature, or piety. The investigator is a law unto himself, and he must often shatter old tables of value and propound new ones. "The spirit goeth wherever it listeth" and we can not tell "whence it cometh or whither it goeth, such are they who are born of the spirit."

Now, universities are to-day, or should be, true shrines of this spirit and nurseries of these supermen. Are they? Over two hundred of them have lately made "drives" that have brought generous and greatly needed increases of salary to their professors. Labor, too, has doubled its wage, but the complaint is universal that along with increased pay has very commonly gone a decrease in the quality and

quantity of efficient work or service rendered. The worker "sojers" more on his job, and not only the hours but the amount of work per hour has decreased; as also has the quality of many kinds of goods along with the rise in their price. The bricklayer is now penalized by his union if he lays more than one-fourth the number of bricks per day he did when his wage was half its present amount.

Are our Faculties to illustrate the same tendency? In a number of presidential reports I have lately looked over I find no word of warning against this danger, no hint that to whom more is given will more be required, no exhortation to investigation, but usually the old cry for more, ever more gifts. Not content to stand hat in hand on the street corner, academic agents and presidents appeal to every graduate, poor as well as rich, to give, until they are made to feel that they are ingrates or disloyal if they are unable to do so. These reports often complain of a great influx of students, and all our larger institutions are already too full for efficiency so that some have even forsworn new departments or set a limit to the rush of students. Two reports express the fear that the average quality of the latter is declining, and one deplores the increase of mechanism, bookkeeping, and deans' functions generally, which are necessary for the regimentation of the mob of new applicants. One very competent expert has studied the programs of the meetings of various scientific societies during last Christmas week, with the result that several show in recent years a very marked increase in the percentage of papers read by non-academic men (80% now in one of the largest and oldest of them), which is not surprising when we consider the great number of professors now being lured away from colleges and universities by larger salaries offered them to become experts in industry, which has apparently just now awakened to the need of specialists.

Now, if there is any one general lesson of these tumultuous times, any conclusion that underlies and conditions all others—as I insist there is—it may be stated very simply as follows. Henceforth, as never before, progress is committed to the hands of the intellectuals and they must think harder, realizing to the full the responsibilities of their new leadership. Science in its largest sense is from this time forth to rule the world. The age of *laissez faire* is ended and research, discovery, investigation, and invention, which have done so much already, must now take the helm and be our pioneers in this new era. In everything it is the expert who must say the final word. Thus our prime duty is to inventory and especially develop and devise every possible new way of fostering the spirit of original research in this new day that is now dawning upon the world, and in which it is the inestimable privilege of this generation to live. We can not too clearly realize or too often repeat that research is in the very center of the current of creative

evolution and has the momentum of all the developmental urge behind it. Its spirit is to the new era what the Holy Ghost was to the early church. Once it made prophets and apostles, inspired visions, sent men to waste places to meditate as hermits, anchorites, ascetics crucifying the flesh, or impelled them to challenge rulers or to become martyrs. Now it inspires men to seclude themselves in laboratories, museums, studies, libraries; sends them to remote and perhaps hostile and dangerous corners of the earth to observe, collect, excavate, decipher, reconstruct extinct animals from fossils or fragments of bones and teeth, or to restore prehistoric life from vestiges and utensils in caves, cromlechs, relics of pile-dwellers; or to reconstruct temples, palaces, dwellings, and even huts from their buried foundations; perhaps to explore the sources of mineral, agricultural, and industrial wealth; or to study and control the ways of and antidotes for new microbes, insect pests and toxins. Human culture began with the attempt of man to understand his own soul, its nature and destiny; and to this was soon added interest in his body and its diseases. Now we are studying his relations to his home and his mother, Nature, and his social, industrial, and family life.

When I lately asked my dentist why he hurt me so cruelly now when the same operation on the other side eight years ago was painless, he replied that now he had to use American instead of German novocain and we have not learned to make the pure article. In looking over Kahlbaum's catalogue of hundreds of chemical compounds necessary for every research laboratory, I was told that only a very few of them can even yet be produced outside of Germany and that our chemical industries have focussed upon nitrates, dyes, and other large-scale products that bring great profits.

Turning to other departments, ever since the Reformation German scholarship has led in all Biblical studies, giving us the higher criticism, and its preëminence has been no less in the study of classical texts and history. Our professors of philosophy have largely concerned themselves with problems of German origin from Kant to Schopenhauer and Nietzsche. Biological work has for two decades focussed on the theories of Weismann and Mendel, both Teutonic. In every psychological laboratory the name of Wundt outranks all others, while Freud has more lately given us another group of great ideas which are working as leaven not only in the studies of mind normal and abnormal, but in our conceptions of art, literature, daily life, history, and religion. Students of the exact sciences are agog over the theories of relativity as represented by Einstein and the even more revolutionary concept of quanta, also of German origin. For decades our best graduates who desired to specialize studied there and a large part of our professors have been trained there, so that the apex of our educational system was long found beyond the Rhine.

All this was in accordance with the policy laid down by Fichte only a little more than a century ago in his famous address to the German nation when Napoleon had annihilated the Teutonic armies, crushed the German spirit, and his spies were scattered through the very hall. Fichte's thesis was that Germany must become *the* educational leader of the world and must thus rehabilitate herself from bottom to top and understand that her only possible way of escaping obscurity, if not annihilation, was research, her only asset was in the truth to be discovered and new powers to be utilized. In a word, her soil was poor, her armies gone, her finances ruined, her spirit near despair, and the gospel of Fichte, the "presentifier" of his day, was that all the power she could ever expect in the future must come from knowledge—that her specialty must be in its creation and diffusion. And the world knows the result of this policy, which in a century made his country the strongest in all history, which never saw so brief and great a national regeneration in the same short span of years.

To-day this leadership is gravely impaired, and possibly forever shattered, and it is craven and imbecile not to see that the situation brings a new call to this country, now the richest and most prosperous in the world—spending more money for education, we have just been told, than all Europe combined—to aspire to this succession, to pay back our intellectual debt, and possibly to bring the keystone of the educational arch again to this country. Of course we must not forget, as Kuno Francke reminds us, that Germany in her present distress may again hark back to the gospel of Fichte and seek to renew her strength by a yet more intensive development of culture and hope to sometime achieve a new intellectual conquest of the world, such as she was so far on the way toward achieving when she turned from culture to Kultur and, at length, not content with this, made her supreme error of appealing to the sword. Of course science is universal and knows no national boundaries, but our nationality, whatever it is and is worth, has here a new opportunity undreamed of before.

Not only does democracy, if it is to be made safe for the world, require education of its citizenry much above the mental age of thirteen and a half, which was the average of our soldiers tested, (and we have even been called a nation of sixth-graders), but every land —and this most of all—is now crying out for new leaders in every department. Our statesmen need broader training in international relations and show every symptom which alienists find in all minds grappling with problems too large for their powers. Our captains of industry need to look farther afield and farther ahead. The waste of incompetency and the curse of mediocrity are upon us. We have utterly lost all power of discriminating between the best men, things, ideas, books, and the second or even the tenth best.

The psychology of the whole matter is that we love knowledge because we love power. As man has domesticated some two hundred species of animals, using for his own benefit their strength, instincts, keener senses, etc., so he strives to command the powers of nature and to really become the captain of his own soul. Competent engineers tell us that the average individual to-day commands some thirty-three man-power besides his own, whereas a century ago all inventions gave him command over only two and a half times his own strength. But ever more is and will be needed although waste also increases, and all we have known and controlled is only the beginning. Man is really only just starting on his career as an investigator so that thus research is not only the apex of creative evolution and the highest vocation of man but is the greatest joy that life affords to mortals. He who reveals and teaches us to command more of the world without and within is the chief benefactor of the race, the true prophet, priest, and king in our day.

Now, probably the university should be the chief shrine and also the power-house of this spirit, which ought to be for the new post-bellum epoch now opening what the Holy Ghost was to the early church, for in it the higher powers of man have their chief deployment. There is a final lesson from the church that we ought to lay to heart. Beside and above all its elaborate medieval organization, even when it was at the height of its power and aspired to universal dominion, its greatest leaders always felt that above and beyond it was the larger Church Invisible, eternal, not made with hands, the membership of which consisted of everybody, everywhere, who strove supremely for righteousness and truth. To-day we should give a similar place in our scheme of things to the University Invisible, composed of all those everywhere who are smitten with the passion of adding something to the sum of the world's knowledge, even ever so tiny a brick to the splendid temple of science, which is the supreme creation of man, but who realize that of this temple only the foundations are yet actually laid and that the most imposing part of the structure is not only not built but can not even be completely planned. The members of this new church of science are those who feel the call to make some original contribution of their own toward either its plan or its further structure, for the true university is, after all, only found in the investigator's state of mind. All through the history of the church, as Renan has shown, ran a faith generally submerged but which had many timid out-crops that in the fullness of time there was to come a new, third dispensation superseding the old, *viz.*, the dispensation of the Spirit. It is that into which we are now summoned to enter. Have we the virtue to hear and heed the call?

SWISS GEODESY AND THE UNITED STATES COAST SURVEY[1]

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THE influence of the intellect transcends mountains and leaps across oceans. At the time when George Washington warned his fellow countrymen against entangling political alliances with European countries, there was started a movement of far reaching scientific importance in a small country in the heart of the Alps which (as we shall see) exerted a silent, yet potent scientific influence upon the young republic on the eastern shores of North America. Our government executives can restrict the movements of troops and can abstain from making hazardous treaties, but these policies can not permanently check the subtler movements of intellectual thought which often, like aerial waves, encircle the world.

In 1785 a gifted and enthusiastic young German named Johann Georg Tralles became professor of mathematics and physics at Berne in Switzerland. Interested in applied as well as pure mathematics, Tralles was active as a metrologist and geodesist. Maps of that part of Switzerland had been altogether unreliable. He entered upon refined surveys of the triangulation type. In this work he was assisted by one of his pupils, Ferdinand Rudolf Hassler of Aarau, a young man who belonged to a well-to-do family. His father had mapped out for him a bureaucratic career which would have brought a good competence. But the mathematics and the surveying instruments of Tralles exerted an attraction impossible for him to resist. In 1791 Tralles and Hassler measured a base-line together, using a steel-chain manufactured by the English mechanic Ramsden. The base line was 40,000 feet long; its ends were marked on blocks of stone four feet high, with steel points held in position by cast lead. Not satisfied with the accuracy reached, a few years later they remeasured this base with improved apparatus. Carefully standardized rods now took the place of chains. A net of triangles was adopted, the principal points of which were the several summits of the Jura mountain range. For the great distances between stations the instruments were found to be inadequate. Tralles wrote to a friend about his angular measure-

[1] Sigma Xi address delivered at Northwestern University on December 13, 1920.

ments: "I have tortured them out with a theodolite—measurement I can not call this, when the telescope is so weak that one can not see the signals, but only guess their position. You can readily see that they are not small, for the telescope of the theodolite reveals them at a distance of 100,000 feet." The government of the Canton of Berne was appealed to for financial aid in the purchase of a more powerful instrument. Six hundred dollars were voted immediately. Mr. Ramsden in London, then the most celebrated instrument-maker living, for a sum somewhat exceeding this amount, promised to supply in 1794 a complete azimuth circle, at least three feet in diameter. Due to various delays the great instrument did not reach Berne until 1797. Meanwhile some smaller instruments had been secured from England; Tralles and Hassler had been active in perfecting their technique. Young Hassler received the commission to determine the boundary line between the Cantons Berne and Solothurn. Ramsden's three-foot theodolite was a wonderful instrument; only two other instruments of that size and precision are said to have been manufactured by Ramsden. What a privilege for young Hassler to become practically acquainted with the use of an instrument of the high type that very few surveyors then living had ever seen!

Hassler repeatedly took trips to Paris and one trip to Germany; he attended lectures and became personally acquainted with leading scientists—among them Lalande, Borda, Delambre and Lavoisier in Paris; Von Zach and Bohnenberger in Germany. With funds liberally supplied by his father, Hassler purchased many instruments and scientific books. He astonished Von Zach late one afternoon by measuring with a five-inch English reflecting sextant and mercury horizon the latitude of Zach's observatory and differing only five seconds from previously known determinations. We see Hassler occupied with serious studies and becoming familiar with the practical operation of the most refined mathematical instruments in existance at the time.

Geodetic work in Switzerland was stopped by revolutionary events. In 1798 French soldiers marched into Berne. Friction arose between Franch and Swiss goedesists. A few years passed without bringing relief. Hassler who meanwhile had married and had held various official positions of responsibility in his canton of Aargau became weary of European turmoil, and decided to seek his fortune in the New World. Strange to say we find him engaged in the organization of a stock company for the purchase of large tracts of land in South Carolina. In 1805 he departed with wife, children, servants and 96 trunks, boxes and bales, and travelled down the Rhine, having previously chartered in Amsterdam the ship "Liberty" (350 tons) for Philadelphia. He was accompanied on his trip by over 100 laborers to form a Swiss colony in the South. Unfortunately Hassler's agent speculated with

the funds entrusted to him and Hassler sustained heavy financial loss. He arrived in Philadelphia without means to support his family. While waiting for remittances from his father, he sold some of his books and instruments. He received financial assistance also from John Vaughan, a prosperous and public spirited Philadelphian.

Hassler soon got in touch with scientific men in Philadelphia. He attended meetings of the American Philosophical Society. On December 6th, 1805, he donated to this Society a model of Mont Blanc, two chamois horns, and a specimen of feldspar. Hassler was elected a member of the Society on April 17th, 1807. The year previous he had sold to the Philosophical Society "the volumes necessary to complete the transactions of the French Academy of Science of which the Society possessed eighty-nine volumes, the bequest of Dr. Franklin." Hassler sold also some volumes of the transactions of the Berlin Academy. I mention these items to indicate the kind of books Hassler brought to America.

He brought also a number of instruments and standard weights and measures, such as had never before been carried to the American shores. Among these were a standard meter, made at Paris in 1799 by the Committee of Weights and Measures, a standard kilogram, an iron toise, made by Cavinet in Paris, two toises of Lalande. All of these were acquired by the American Philosophical Society and were loaned to Hassler twenty-six years later when he was acting in Washington as superintendent of weights and measures.

In 1806, Professor Robert Patterson and John Vaughan in Philadelphia, John Garnett of New Brunswick and others were deeply impressed by the ability and enthusiasm for science displayed by Hassler. Patterson was then director of the United States Mint. Feeling no doubt that the services of this talented young man of 36, whose long course of special training secured in Switzerland, France and Germany, made him one of the very foremost living practical geodesists, should be enlisted by the American Government, Professor Patterson gave President Jefferson an account of Hassler's life. "He would willingly engage," said Patterson, "in an exploring expedition, such as those you have already set on foot."

As neither Patterson's letter to President Jefferson, nor Hassler's brief autobiography enclosed with it, has ever appeared in print, it may be interesting to present these documents, at least in part.[2] Professor Patterson wrote:

[2] For copies of these documents, and of the letters written by President Jefferson and President Madison which we quote later, we are indebted to the kindness of Dr. Anita Newcomb McGee of Washington, D. C. The originals are in the Manuscript Division of the Library of Congress. Dr. McGee is a great granddaughter of Hassler.

(From Robert Patterson, Director of the Mint, to Jefferson.)

Philad. March 3d 1806.

"Sir

"I beg leave to introduce to your notice Mr. Hassler, a gentleman lately from Switzerland. He is a man of science & education; and, as will appear from the enclosed paper, written by himself at my request, was a character of considerable importance in his own country. It is his wish to obtain some employment from the United States, which would require the practice of surveying or astronomy. He would willingly engage in an exploring expedition, such as those you have already set on foot; for which, I have no doubt, he would be found well qualified.

"In his education he paid perticular attention to the study of astronomy, and statistical surveying; & from the enclosed paper you will see, that he is well versed in the practice. He is a man of a sound, hardy constitution, about 35 years of age, & of the most amiable conciliating manners. Besides his knowledge of the Latin language, he speaks the German, French, Italian & English. To his acquaintance with mathematics in general, which, as far as I am capable of judging from a short though not slight acquaintance, is very extensive, he adds a good knowledge of chemistry, mineralogy, and all the other branches of natural philosophy. In short, Sir, I believe his services may be rendered useful to this his adopted country. He possesses a very valuable library, and a set of surveying & astronomical instruments, scarce inferior to any I ever saw.

"I shall only add, that the cause for which he struggled in his native country, and the reasons for his seeking an asilum here, will not, Sir, I am sure, detract from his merit in your estimation.

"I have the honour to be,
"with sentiments of the
"greatest esteem,—
"Your most obedient servt.
R. Patterson.

"P. S. I forgot to mention, that Mr Hassler is at present settled with his family (a wife & three children with a few domestics) on a small farm near the banks of the Schuylkill, and that he proposes very shortly to pay a visit to the seat of government."

Hassler's sketch of his life which was enclosed in the letter that Patterson sent to President Jefferson, is reproduced here with all its orthographic peculiarities:

"Feb. 27, 1806.

"After my first education in public and private schools at Arau, my native town, I went in my 16th Year 1787 as a Voluntary in an

office of the government of Berne, appointed for all kind of surveyings and the care of the archives of the state, in which businesses I worked; following at the same time the lessons of the College, then newly established under the name of political institute, and the private instructions of Mr. Tralles Professor of Mathematics, (now member of the Academy of Berlin) aplying chiefly to practical geometry & astronomy. As a practical exercise of these instructions Mr Tralles & I undertoock in 1791. (on my expenses) the trigonometrical mesurements for a map of the country, and mesured a base of 7¾ Miles length and some triangles, with proper means and instruments, till the season interrupted the further prosecution.

"The Government of Berne, seeing the various advantages of this Work, undertook to follow it, and appointed proper funds for the instruments; which were comitted to Mr Ramsden in London.

"In 1792 I went to the university of Göttinguen, (staying a short time in my passage at the Observatory of Mr de Zach at Seeberg) where I continued my studies in mathematics and natural Philosophy, under Kästner and Lichtenberg; (with whom I was particularly acquainted): Obliged nevertheless by the wishes of my father, to give some time to the study of Diplomatics under Gatterer.

In 1796, I went to Paris applying half a Year chiefly to Mineralogy & Chymistry under Haüy, Vauquelin, Fourcroy &c. (being already acquainted by a former Voyage there with LaLande & Borda.)

In 1797. a large Theodalite of Ramsden beeing arrived at Berne Mr Tralles & I endeavoured to prosecute now for the Government the Geographical Operations begun in 1791. but ware soon stoped again by the Revolution of Switzerland early in 1798. which event changed at the same time my position by annulating a post of my father the succession of which was secured to me since my 16th Year.

Though the ministry of Finances of the Helvetic Republic, desireous of an accurate mape of the country gived me on a new the commission to follow the Work and I worked at it a short time in 2 Seasons the perpetual changes & finally extinction of the unitary Government put an end to this Work for which I could neither get my advances repayed nor my Labour. On my leaving the Country I left the unfinished Work to one of my friends to be sold for a trifle to the new Government.

Though I took no trouble to get any public office I was early in 1798. elected to the Court of appeal of the Canton of Argovia for the direction of criminal affairs, (accusateur public) from which place I was called in 1799. by the Central Government to the same functions at the Supreme Court of the Helvetic Republic, after the extinction of which in 1803, I went at home were I was elected by the representatives of the Canton a member supleant of the Court of Appeals, and by my

fellow-Citizens a member of the Counsel of the town, in which I was trusted with the chief Direction of public buildings and Archives.
But foreseeing the constant oscillations in the state of the Country involving always my position according to past experiences (intrigues and ambition, which are wanted in such circumstances, beeing out of my Caracter) I took with some of my friends the resolution to come over to America in search of more solidity in a peaceable Country.
Though I shall be one of the Directors of a Society of my countrymens intending to come over in this Country my presence beeing not always nor absolutely wanted, I could and wished to be employed in some business where practical Geometry & Astronomy would be the requisites, by preference.
Philadelphia 27th Febr: 1806: F:R:Hassler."

In addition to Professor Patterson's letter and enclosure, President Jefferson received a letter from Dr. C. Wistar of Philadelphia, recommending Hassler. President Jefferson's reply to Dr. Wistar, which has never been printed, is as follows:

"Yours of the 19th, [February 19th 1807] has been received, as was a former one proposing Mr. Hassler to be employed in the survey of the coast. I have heard so much good of him as to feel a real wish that he may find the employment of the nature to which his physical constitution & habits may be equal. I doubt if. in yielding this as to Mr. Hassler, I transgress a principle I have considered as important in making appointments. The foreigners who come to reside in this country, bring with them an almost universal expectation of office. I recieve more applications from them than would fill all the offices of the U. S. * * * It is true there are some employments * * * into which meritorious foreigners & of peculiar qualifications may sometimes be introduced. such is the present case."

It appears that the starting of the survey of the coast of the United States was taken under consideration by members of the American Philosophical Society at Philadelphia for the reason that there had come into their midst a man preeminently qualified to undertake such a survey. In other words, had Hassler not come to the United States, probably no effort would have been made at that time to organize such a survey. Upon President Jefferson's recommendation, Congress passed a law, authorizing a survey on February 10th, 1807, and made an appropriation of $50,000. Albert Gallatin, Secretary of the Treasury, addressed a circular letter to scientific men, asking for plans for carrying the survey into effect. Among the replies were letters from Robert Patterson of the U. S. Mint, James Madison, then President of William and Mary College, Andrew Ellicott who had long been active as a surveyor in the United States, John Garnett of New Brunswick who

was interested in astronomic and geodetic affairs. Hassler's reply was written in the French language; it carefully outlined a trigonometric survey and the use of chronometers in localities where trigonometric surveys would be very difficult. At President Jefferson's direction, a commission passed upon these plans. That Hassler's plans would be chosen seemed to be a foregone conclusion in the minds of most scientists interested. The commission was formed of the very men who had submitted plans, with the omission of Hassler, who was then at West Point. In rejection of their own plans, they recommended Hassler's. On account of political disturbances in Europe and America the survey was not begun in 1807. Meanwhile Hassler had been appointed acting professor of mathematics at West Point, where he served two years. Later he was for one year professor at Union College at Schenectady.

During his residence at West Point and Schenectady he had occasional correspondence with Patterson regarding details for the coast survey, especially the necessary instruments. On September 2, 1807, Patterson asked him by letter whether he would be willing to go to London to direct the construction of the instruments there. Hassler expressed his willingness to undertake the mission, but not until August, 1811, was the government able to send him. Hassler embarked with his large family for England.

After the death of Ramsden, Edward Troughton came into ascendency as a skilled mechanic. It was his ambition in life to surpass Ramsden as an instrument maker. Hassler set Troughton and others to work, manufacturing under his direction instruments for the United States Coast Survey. Some of the principal instruments were of Hassler's own design. He secured instruments and books also from Paris. Politically the time was unfavorable; the war of 1812 broke out. Hassler was in the country of the enemy. Once he was refused a passport in London until after a personal application was made to the foreign secretary, who granted the passport with the generous remark "that the British Government made no wars on science."

The total amount expended for instruments during four years in England and France was $37,500; including books, Hassler's salary and travelling expenses, the outlay exceeded $55,000. Troughton, the celebrated London instrument maker, remarked that there was not so complete and useful a collection of instruments in the possession of any government in Europe.

On October 16, 1815, Hassler informed Mr. Dallas, then Secretary of the Treasury, of his safe arrival with the instruments, in Delaware Bay; they were deposited at the University of Pennsylvania. Some of the instruments were intended for use in two astronomical observatories that were to be established according to Hassler's plans which

had been matured some time in the interval 1807-1811. He brought back all the instruments then deemed essential for the astronomical observatories except a mural circle and zenith sector, which he "did not venture to order, as their absolute necessity, in connection with the survey of the coast, was not so obvious as that of the instruments procured."

"To procure the greatest advantage to the survey," continued Hassler, "their positions [positions of the observatories] should be as far North East and South West as the very favorable position of the United States admits"—one in the district of Maine, the other in Lower Louisiana. "Nearly every celestial phenomenon observable from the tropic to the arctic circle and within about two hundred degrees of difference of longitude, could be observed at one or the other of them." Little did Hassler realize at that time that over a quarter of a century would elapse before Congress would authorize a national astronomical observatory.

Not until May 2, 1816, did Congress pass appropriations for the survey of the coast. In August of the same year Hassler was appointed Superintendent of the Survey of the Coast. In his eagerness to begin work Hassler had gone to Long Island and reconnoitered the neighborhood during the month before his regular appointment. At first he had only three inexperienced cadets from West Point to help him; in September, Major Abert, one of his West Point acquaintances, was detailed to assist him. Great difficulty was experienced in finding a satisfactory locality for the measurement of a base line. Bad weather caused further delays. Once his work was interrupted by a law-suit brought by a man who charged that Hassler had cut off some branches of a cedar bush, to make the remaining part of the bush answer as a temporary signal. There were no railroads in those days; public highways were few. Hassler's work took him to localities not easily reached. For conveying of himself, his men and his delicate instruments, he had constructed early in 1817 a spring carriage, of special design, to be pulled by two or four horses. This carriage became famous because of its odd appearance and because political opponents of Hassler charged that he indulged in luxurious travel, such as was enjoyed by no other government official.

Delays occurred also because of tardiness on the part of the Government in sending the necessary funds. At times Hassler advanced money of his own, to prevent interruption of the work. The difficulties experienced from wooded marshes and the absence of sharp points near the coast made it necessary for him to plan for a full chain of triangles back from the shore. The proper locality for a base was not found until April, 1817. In February the Secretary of the Treasury asked Hassler to state the probable time required for the execution of the

survey. This was a disquieting question; as yet, the survey had hardly begun! In the Canton of Berne, Switzerland, four years had been considered none too long a period for a much smaller project. With Major Abert as his only trained assistant, Hassler worked during 1817 from the opening of the season in April until the end of December, when none but Hassler "thought it possible to stand it any longer" on account of the cold. He worked early and late, whenever weather permitted, and displayed an enthusiasm seldom equalled. At that time Hassler knew little about American politics. He proceeded on the supposition that if he maintained high scientific standards, if he worked hard and faithfully, his services would be appreciated. He learned by sad experience that this is not necessarily the case, that the head of a government scientific bureau must take pains to keep in touch with political leaders and through personal contact and courtesies extended must endeavor to secure the interest and good will of these leaders; in other words, that political leaders must be educated to the appreciation of science. Hassler did not work in Washington at that time. In winter, when work in the field was impossible, he resided in Newark, New Jersey. Even if he had tried, it would have been difficult to have kept in touch with Congressmen.

In 1817 eight triangles were formed, determining the distances of about forty points with great accuracy; two bases were measured; latitudes and azimuths were ascertained. After December, the winter was passed in performing the necessary computations. On April 6, 1818, the Secretary of the Treasury apprised Hassler of the fact that the little progress made in the survey had caused general dissatisfaction in Congress. This was a bolt from an almost clear sky. Hassler replied by telling what had been accomplished—more than double what had been achieved in the English survey in the same time. After sending this reply, Hassler, who was in Newark, concluded that he had better go to Washington with all his documents, so that he could offer any explanation desired. His explanations to the Secretary of the Treasury were of no avail; on April 14, 1818, the law authorizing the survey was so modified by Congress as to exclude Hassler, a civilian, and leave the survey in charge of military and naval officers.

The fundamental difference between Hassler and Congress was that Hassler aimed to make a triangulation survey that would be a credit to America in the eyes of scientific men of the world; such a survey requires time. Congress, on the other hand, had no intention of aiding science; they wanted a map of the coast and that without delay.

Terrific as this blow must have been to Hassler, he took it calmly. Defeats never subdued him; they spurred him on to renewed efforts. Krusenstern wrote him from St. Petersburg, "In Russia your talents would have been better appreciated."

For fourteen years nothing creditable was done on the coast survey. No one connected with it had the training, experience and vision to carry it on successfully. These years constitute the dark ages of the United States Coast Survey.

For Hassler these fourteen years from the age of 48 to 62 should have been scientifically the most productive years of his life; but eleven of the fourteen were the most barren. We pass in silence his years of struggle to support his large family, years during which the operation of a farm in northern New York proved financially disastrous, years during part of which his energy was dissipated by school teaching in small private academies and in the compilation of elementary text-books; years of mental anguish over the breaking of family ties. I may add parenthetically that Hassler had nine children, several of whom died in childhood. Hassler's eldest son has many descendants in this country. Hassler's son, Charles Augustus, was a surgeon in the U. S. Navy and was the father of Mary Caroline, wife of the late Simon Newcomb, the astronomer. Mrs. Newcomb is now living in Washington.

In 1830 Hassler was placed at the head of the work of weights and measures—a scientific department of the Federal Government organized by him. His ten years of preparation in Switzerland and his trips to France and Germany fitted him admirably for such work. Finally in 1832, when Hassler was 62 years old, Congress experienced a lucid interval and re-enacted the law of 1807 on the Coast Survey. Hassler was reinstated as superintendent. For eleven years he labored assiduously, until death claimed him. During that time the Coast Survey advanced with rapid strides, notwithstanding continual interference by government officials and members of Congress.

Hassler remained mentally alert to the very last. He kept in touch with geodesists and astronomers of Europe. He was in correspondence with Gauss of Göttingen. He was in touch with Bessel who wrote a critical yet very appreciative review of Hassler's description of his plans and instruments for the U. S. Coast Survey, printed in 1825. Bessel saw in those plans original features which placed them higher than any plans then in operation in other countries. Hassler was in regular correspondence with Schumacher, the editor of *Astronomische Nachrichten;* with Admiral Krusenstern and the elder Struve in Russia; Hassler communicated with the astronomer Tiarks and with Edward Troughton in England; occasionally he contributed papers to European journals. He was an associate of the London Royal Astronomical Society. In our country he kept in correspondence with Thomas Jefferson and James Madison. Thus, instead of living a submissive, passive life, instead of vegetating, he kept his mind alert, young and creative.

The reader may be interested in an unpublished letter which ex-

President Madison wrote Hassler on February 22, 1832, when Madison was in his eighty-first year:

Montpelier, february 22, 1832.

Dear Sir:

I have received your favor with the accompanying copies of your report on weights and measures. I have forwarded the two, one for Professor Patterson and one for the University of Virginia, and shall dispose of the others as you desire. For the copy allotted to myself, I return you my thanks. The decrepit state of my health, added to my great age and other causes, have prevented me from looking much into the work. My confidence in your aptitude for it, takes the place of a positive proof of its merits.

I am glad to learn that you are to resume the important labor of surveying the coast. I hope you will be able to complete it; and to your own satisfaction, in which case I doubt not it will be to the satisfaction of those who invite you to the undertaking.

I tender you sir my esteemed friendly salutations.

(Signed) James Madison.

The creative side of Hassler is seen mainly in the design of new instruments. He put forth an improved repeating theodolite. For signals at geodetic stations, Hassler, in 1806, recommended spherical reflectors, such as he had used in Switzerland, but later introduced truncated cones of tin which could be manufactured easily and cheaply and under ordinary and easy conditions, possessed advantages over the heliotrope invented later by Gauss. Hassler appears to be the earliest geodesist who thought of using the bright reflection of solar light from a gilt ball or cone. After 1836 Hassler used Gauss' heliotrope for great distances to be pierced under bad atmospheric conditions. Most original was Hassler's base line apparatus which involved an idea worked out by him in Switzerland and perfected in this country. Instead of bringing different bars in actual contact during the progress of base-measurements, he used only one bar and *optical* contact. Each end of the bar was marked by a spider web; a compound microscope standing upon a separate support was placed at the forward end, right over the spider-web. As the place of this end of the bar was determined by the microscope the bar could be moved forward and its back end placed under the microscope. This was truly an ingenious procedure.

It is interesting that Hassler's plans for an observatory in the United States which were presented to the Government in 1816 and published in 1825 should resemble those actually carried out later by Schumacher in the Altona Observatory in 1826. From obvious principles both scientists deduced independently of one another, plans closely resembling each other.

In the making of maps, Hassler used what is now called the American polyconic projection. This projection was well adapted for the eastern coast of the United States which is a narrow strip extending ap-

proximately north and south. Mr. C. H. Deetz of the Coast and Geodetic Survey, says that "Hassler's polyconic projection possesses great popularity on account of mechanical ease of construction and the fact that a general table for its use has been calculated for the whole spheroid." "It has," adds Mr. O. S. Adams, "been extensively used by the United States Coast and Geodetic Survey."

When Hassler resumed work on the Coast Survey in 1832 his health was somewhat broken, but his mind was clear and his spirit unbroken and defiant of his opponents, to the very last. "Difficulties have never subdued me in my life," "I have worked in sick days and in well days" are statements the more impressive, when we recall his struggles against poverty, the large family dependent upon him, the illness of his children, his serious family vicissitudes, the advantages taken of him by supposedly personal friends, the limitations placed upon him by government red tape, and the political attacks hurled against him. In these respects his career resembles that of the immortal Kepler.

In his struggles with government officials, Hassler insisted that for the greatest success of the Coast Survey, the Superintendent must be given liberty to hire men whenever the work required it, to arrange for transportation of instruments by land or water, the purchase of instruments and books within the limits set by the appropriations made by Congress. This liberty, said Hassler, the Superintendent of the Coast Survey should have, just as a sea-captain is allowed "to set the sails of his vessel according to the wind and sea." Hassler's signing the list of accounts with the statement "these expenses were incurred in consequence of my direction for the survey of the coast" were objected to by auditors of the treasury department as insufficient. Hassler entered a vigorous protest and in this struggle won out on many points.

A bone of contention was Hassler's salary. An anecdote became current about 1836 that Secretary Woodburry and Hassler could not agree on this point, and that Hassler was referred to President Jackson. "So Mr. Hassler, it appears the Secretary and you cannot agree about this matter," remarked President Jackson, when Hassler had stated his case in his usual emphatic style. "No sir, we can't". "Well, how much do you really think you ought to have?" "Six thousand dollars, Sir." "Why, Mr. Hassler, that is as much as Mr. Woodbury himself receives." "Mr. Voodburry!" declared Hassler, rising from his chair, "there are plenty of Voodburrys, plenty of Everybodys who can be made Secretary of the Treasury. But," said he, pointing his forefinger toward himself, "there is only one, *one* Hassler for the head of the Coast Survey." President Jackson, sympathizing with a character having some traits in common with his own, granted Hassler's demand.

One objection raised to Hassler in Congress was that his survey was too slow and expensive; a modified, less scientific, more expedi-

tious plan was advocated. As we look back now after the passage of four score years, Hassler stands out greatest in perceiving and singling out what was best in the practical goedesy of his time, in making improvements upon what he found, and then clinging to his plan, which was a triangulation scheme, as being the best that the science of his day brought forth—clinging as a mother does to her child in danger. What looms highest is his moral quality and strength to resist compromises, to resist hazardous alterations suggested by engineers and statesmen, to maintain this opposition against the adoption of "cheaper" yet "just as good" plans, and to persist in this opposition year after year, decade after decade, from young manhood to old age. The services of Hassler to the Nation loom larger and larger with the lapse of time. Hassler scorned pretensions and shams. Says a recent writer: "Due to his far sightedness the best foundation was thus laid for geodetic operations."

Switzerland, at the close of the eighteenth century, embodied in its triangulation surveys the best that European science could offer. Tralles and Hassler introduced some novelties of their own. The Swiss science and art of geodesy were carried by Hassler to the United States. Keeping in constant touch with European progress, Hassler exercised his genius in adopting European practice to American conditions and adding improvements of his own. Thus, Switzerland became the mother of American Geodesy.

THE HISTORY OF CHEMISTRY—II.

By Professor JOHN JOHNSTON
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Development of Organic Chemistry in the Last Fifty Years

THE science of organic chemistry developed, as we have seen, very slowly until consistent ideas as to the mode of combination of the elements, and consequently as to the structure of compounds, were established; but since then its growth has been by leaps and bounds. To-day the organic chemist has prepared, described, and ascertained the constitution of compounds numbering 150,000 or more; amongst these, in addition to a large number which had previously been isolated from natural products, are a vast number never known until built up in the laboratory. Indeed as soon as he established the structural principles upon which organic compounds are built up, he became an architect and designer of chemical structures, using as units the radicles or groups, and proceeded in his laboratory to learn how to build up such structures. And so it is now possible to synthesize in the laboratory a relatively complex substance such as uric acid from its elements; or, starting from benzene or napthalene, the chemist may finish with a dye-stuff, a regular skyscraper of a compound whose structural formula fills half a page and whose systematic name requires several lines of type in more than one font.

In this connection it may be remarked that the so-called coal-tar or aniline dyes bear about the same relation to coal-tar or aniline as a steel battleship does to a heap of iron ore, the latter being merely the raw material from which the former is fashioned. Moreover, an artificial or synthetic substance is no imitation or substitute, but is the real thing and indeed is often purer and better than the natural product; synthetic indigo is real indigo, a synthetic ruby is a real ruby, the only difference being that one is produced by what we are pleased to call natural processes, whereas in the other the process is controlled so as to yield a pure product.

The successful synthesis of a substance is usually not possible until its structure has been established, a matter which may require long-continued laborious effort and analysis; even then it may be realized very slowly, for one must learn how to make his units combine to form the structure desired. Successful synthesis in the laboratory does not imply that this synthesis will directly be carried out on a large scale;

the development of an economically feasible scheme of operations requires a time measured in years rather than in months—even in wartime, when considerations of financial economy are secondary and when more effective co-operation can be secured, the interval between preparation by the gram and production by the ton is a matter of many months. Indeed in some cases—e. g., sugar and rubber—there is no immediate prospect of synthetic production on any large scale, because the material can be built up in the growing plant—the sugar cane or the rubber tree—at a cost comparable with that of the basic raw material required in its artificial production.

The story of even a single achievement in synthesis would be so long and would involve so many technical details and explanations that it cannot be given here; we shall have to limit ourselves to a mention of some of the outstanding examples, premising that these achievements became possible only because of knowledge slowly accumulated by the efforts of many men possessed by a curiosity with respect to the inwardness of things.

Aniline, discovered first in 1840 as a decomposition product of indigo, was found in coal-tar by Hofmann in 1843; in 1845, after his discovery of benzene in coal-tar, Hofmann could make aniline in large quantities from benzene. In 1856 Perkin, a student of Hofmann, while oxidizing some crude aniline, obtained a dye; this was mauve, the first of the aniline dyes, the starting-point of an industry which has since grown to enormous proportions. In 1868 alizarin, hitherto prepared from madder root, was synthesized, and, within a few years, was being made on a large scale, to the complete displacement of the natural product. Indigo was prepared first in 1870, made from accessible coal-tar derivatives in 1880, but it was not until 1890 that the process was discovered which ultimately proved successful commercially; about 1902 the synthetic indigo came on the world-market, and by 1914 Germany was selling over a million pounds a month at about fifteen cents a pound, as compared with a price four times as great ten years earlier. This list of materials made from coal-tar derivatives could be extended indefinitely to include a whole host of compounds, many of which were not known at all until built up by the chemist, used as dyes or drugs, antiseptics or anaesthetics, perfumes or flavors, and now indeed considered indispensable.

About a hundred years ago, Biot observed that a ray of light polarized in one plane has that plane twisted in passing through certain organic substances; and that the direction and extent of this rotation of the plane of polarization is different for different substances. In 1848, Pasteur—who later elucidated the whole question of fermentation and became the father of the science of bacteriology—observed that ordinary tartaric acid rotates the polarized ray strongly to the right, but that certain tartars yielded an acid called racemic acid, iden-

tical with tartaric acid in every respect except that it was optically inactive. On further investigation he discovered that this racemic acid is a mixture of two kinds of tartaric acid in equal quantities and having equal but opposite effects on polarized light; and that the crystals of the dextro form and of the laevo form differ only as the right hand differs from the left or an object from its mirror-image. Pasteur also found that any organic optically active substance will yield two forms of crystal, left-handed and right-handed, and concluded that in such pairs of substances the arrangement of atoms must in one case be the inverse of the other. There the interpretation of the matter rested until 1874, when van't Hoff and Le Bel correlated the observations by the discovery that the molecule of an optically active organic compound contains at least one so-called asymmetric carbon atom—that is, a carbon atom linked to four different groups—showing that optical activity vanishes as soon as the carbon atom ceases to be asymmetric. This type of isomerism cannot be readily visualized through structural formulae written in one plane; but van't Hoff made it clear by picturing the carbon atom as a regular tetrahedron with linkages extending outwards from the four apices, and by using solid models to represent the compounds. On this basis it is apparent that a molecular structure comprising an asymmetric carbon atom may be either right- or left-handed and that there will be two such stereoisomers for each asymmetric carbon atom present; and the facts have been found to be in complete accordance with these deductions.

The phenomenon of optical activity and its interpretation on a stereo-chemical basis have proved of great usefulness, for it has been to the chemist a very powerful tool in ascertaining the constitution of many organic compounds. Particularly is this so in the case of the sugars which have the general empirical formula $C_6H_{12}O_6$. When Emil Fischer started systematic work upon the sugars, in 1883, practically nothing was known as to their constitution; in 1908, when his collected papers on sugar were published, the complex relationships had been resolved. Fischer had succeeded in determining the structural formula, and in synthesizing, each of the important sugars; he had prepared many of the possible stereoisomers, thereby confirming the usefulness of van't Hoff's theory, and had, indeed, systematized the whole matter. This is only one of his great achievements; for he had simultaneously established the constitution of many compounds of the so-called purin group, a group which includes substances such as caffeine and uric acid. His work on sugars brought in its train the necessity for examining further the nature and properties of substances which bring about the process of fermentation; from this it is but a short step to the proteins, a class of substances more directly connected with life processes than any other. And in this field likewise, which at the outset presented unparalleled difficulties, Fischer progressed a long

way; he was able to break down the complex substances into simpler amino-acids and other nitrogenous compounds, to ascertain the structure of these decomposition products, and by bringing about recombination of these units to prepare synthetic peptides which approximate to the natural products.

The measure of Fischer's achievement in this matter is brought out by a quotation from a short history of chemistry published as recently as 1899:[12]

> Not only the simple formic and acetic acids, but complex vegetable acids, such as tartaric, citric, salicylic, gallic, cinnamic; not marsh gas and ethylic alcohol only, but phenols, indigo, alizarin, sugars, and even alkaloids identical with those extracted from the tissues of plants, are now producible by purely chemical processes in the laboratory. It might appear that such triumphs would justify anticipations of still greater advances, by which it might become possible to penetrate into the citadel of life itself. Nevertheless the warning that a limit, though distant yet, is certainly set in this direction to the powers of man, appears to be as justifiable now, and even as necessary, as in the days when all these definite organic compounds were supposed to be producible only through the agency of a "vital force." Never yet has any compound approaching the character and composition of albumen or any proteid been formed by artificial methods, and it is at least improbable that it ever will be without the assistance of living organisms.

This illustrates again the danger of prophecies as to the limitation of man's powers; for the limitations set are continually being transcended by the genius, and he would be rash who would now set a limit to what may be learned from biochemical investigations, in view of the extraordinary progress made within the present century; but to discuss this fascinating subject is beyond the scope of this sketch of the development of the principles of chemistry.

General and Inorganic Chemistry Since 1860

Compared with the enormous growth of organic chemistry, that of inorganic chemistry was for a long time insignificant. It remained for many years largely in the hands of the so-called practical man, who has been defined as the man who practices the errors of his grandfather; and contented itself largely with descriptions of substances rather than with their interrelations and structure. As one instance among many, it may be mentioned that there has been no real technical improvement in the Chamber Process of making sulphuric acid—which is the key substance, made by the millions of tons yearly, in all chemical manufacture—since Gay-Lussac invented his absorption tower nearly one hundred years ago; nor does this mean that there is no room for improvement, but merely that it was not *sought properly*. Indeed as late as 1900, many chemists considered that but little more, and that *little* not of the first importance, remained to be done in inorganic chemistry; the truth being the exact opposite—that we had then barely

[12] W. T. Tilden, "A Short History of the Progress of Scientific Chemistry," p. 154.

scratched the surface of this enormous field. It had not been adequately recognized that chemistry had been dealing in the main with the behavior of a rather restricted range of substances over a narrow range of temperature (say, from somewhat below the freezing point up to 400°) and, practically, at a single pressure—with a mere slice of the whole field, in fact—and that these conditions are quite arbitrary when we consider the whole subject-matter of chemistry.

Nor is the development of inorganic chemistry of subsidiary importance, from any point of view. If judged with respect solely to the monetary value of its products it would be far ahead of organic chemistry, as will be obvious if we recall that it is concerned with the production of all our metals, of building materials such as brick, cement, glass, and with the manufacture of all kinds of articles in every-day use. One reason for its comparative neglect for so many years is that inorganic chemistry is in a sense the more difficult in that, whereas organic compounds usually stay put and behave regularly—one might say that organic radicles are conservative and conventional—the behavior of many inorganic compounds is more complex, somewhat analogous to that of Dr. Jekyll and Mr. Hyde; another is that the great successes of organic chemistry attracted a majority of the workers. But the main reason is that the proper theories for the interpretation of the phenomena had not been available, consequently proper tools and adequate methods of investigation had not been developed.

The fundamental idea which was lacking is the conception of chemical equilibrium, the importance of which was not really grasped until about thirty years ago and is not yet adequately apprehended by many chemists. The first contribution to this question we need notice dates from 1865, when Guldberg and Waage published the so-called law of mass-action. This paper may be said to inaugurate the quantitative study of chemical equilibrium, though progress for many years was quite slow. Indeed at that time the conception of equilibrium was very recent; of the few cases then known, the majority were certain gases which had been observed to expand with rise in temperature in an apparently anomalous manner as compared to the so-called permanent gases; this anomaly was accounted for on the basis that a progressive dissociation of the gas, e. g. ammonium chloride (NH_4Cl) into simpler molecules of ammonia (NH_3) and hydrochloric acid (HCl), takes place on heating and that the constituents recombine on subsequent cooling. Hundreds of instances are now known, all of which are in quantitative accord with the law of mass-action.

According to this law, the extent of chemical action within a homogeneous gaseous system is determined by the "active mass",—or better, the effective concentration—of each species of molecule taking part in the reaction; this implies that an apparently stationary condition, a

state of equilibrium, is finally reached, at which point the tendency of the reaction to go forward is just counterbalanced by the tendency of the reverse reaction. This may be made more objective by an actual example. By the equation

$$\underset{\text{carbon monoxide}}{CO} + \underset{\text{steam}}{H_2O} \rightleftharpoons \underset{\text{hydrogen}}{H_2} + \underset{\text{carbon dioxide}}{CO_2}$$

we symbolize the fact that under appropriate conditions in any mixture of the gases CO and H_2O some proportion of the gases H_2 and CO_2 will be formed, and conversely, in any mixture of H_2 and CO_2 some proportion of CO and H_2O will be formed; and the law of mass-action states that the concentrations of the several gases will always adjust themselves so that ultimately

$$\frac{[H_2]}{[CO]} \frac{[CO_2]}{[H_2O]} = K$$

where the symbols $[H_2]$, etc., denote the concentrations of the several reacting species, and K is a constant, the equilibrium constant, the value of which depends upon the temperature but not upon the original amounts of any of the substances. From this it is obvious that, if we know the value of K corresponding to any temperature, we are in position to predict exactly what will happen in any mixture in which this reaction may take place, and consequently to select the conditions under which the maximum yield of any one of the substances may be expected. The usefulness of this is so apparent as to require no comment.

The law of mass-action is but a special case of the general question of equilibrium treated so comprehensively by Willard Gibbs, at that time Professor of Mathematical Physics at Yale, on the general basis of the laws of thermodynamics. These two laws now underlie so much of the reasoning upon which advances in chemistry and physics have been based that we must go back a little to consider them.

The doctrine that heat is an imponderable became finally untenable about 1860, when the work of Mayer in Germany and of Joule in England had finally convinced everybody that heat is a form of energy, and that heat and work are quantitatively interchangeable. This leads directly to the First Law of Thermodynamics, the doctrine of the conservation of energy, that energy is indestructible and uncreatable, that energy, though apparently disappearing, is simultaneously reappearing in another form. The second law in its briefest form is that a thermodynamic perpetual motion is impossible; perhaps I can best convey an idea of it by means of the picturesque analogies of a recent writer:[13]

> There is one law that regulates all animate and inanimate things. It is formulated in various ways, for instance: Running down hill is easy. In Latin it reads, *facilis descensus Averni.* Herbert Spencer calls it the dissolution of definite coherent heterogeneity into indefinite incoherent homo-

[13]Slosson, Creative Chemistry, page 145.

geneity. Mother Goose expresses it in the fable of Humpty Dumpty, and the business man extracts the moral as, "You can't unscramble an egg." The theologian calls it the dogma of natural depravity. The physicist calls it the second law of thermodynamics. Clausius formulates it as "The entropy of the world tends toward a maximum." It is easier to smash up than to build up. Children find that this is true of their toys; the Bolsheviki have found that it is true of a civilization.

These two laws, which had been established largely by the work of Mayer, Joule, Clausius and William Thomson (later Lord Kelvin), have only been confirmed by all subsequent work; and they are now considered as fundamental as any laws in physical science. The great advance in applying them generally to chemical processes is due to Gibbs, who in 1876 and 1878 printed in the Transactions of the Connecticut Academy the two parts of his epoch-making paper "On the Equilibrium of Heterogeneous Substances." Gibbs was, however, so far in advance of his time and his paper was moreover so inaccessible, that the importance of his work was not recognized for ten years, when it was proclaimed by Roozeboom and began to be used as a guide—almost entirely by Hollanders and Germans—in the interpretation of chemical phenomena. It is hardly too much to say that the very large number of subsequent advances in this field are merely applications and variations of Gibbs' fundamental considerations; that his paper mapped out the lines of advance in a new field of chemical science comparable in importance to that uncovered by Lavoisier. The conception of equilibrium in chemical processes constitutes the central idea of what is commonly called physical chemistry, which however would be better termed theoretical or general chemistry since it deals with the general principles of the science.

To many Gibbs' name is familiar only as the formulator of the phase rule, a general principle, derived from his thermodynamic discussion of chemical equilibrium, which enables one to sort chemical systems tending to equilibrium into categories, and to state qualitatively what behavior may be expected in each type of system. The phase rule has been of indispensable service in the elucidation of problems as apparently diverse as the constitution of alloys (another large field in which we have done little more than scratch the surface hitherto); the origin of salt-deposits in the earth; the separation of potash or other valuable salts from the waters of saline lakes; the relation between different crystal forms of the same chemical substance, as exemplified in many minerals and in the so-called allotropic modifications of the elements themselves (e. g. diamond and graphite; phosphorus, white and red, etc.). Indeed the service which these doctrines with respect to chemical equilibrium have rendered is but a fraction of what they will render to chemical science, and hence to the people at large.

For a long time there had been investigations looking towards a

relation between physical properties and chemical constitution. An early instance is the work of Dulong and Petit, who discovered that equal amounts of heat are required to raise equally the temperature of solid and liquid elements, provided quantities are taken proportional to the atomic weights; and this was frequently used as a criterion in fixing upon the proper atomic weight. This is an instance of the necessity of comparing quantities which are really comparable chemically, instead of equal weights; that regularities which otherwise would remain hidden will be apparent when an equal number of chemical units —molecules—are considered. Hence it is obvious that few such regularities would be observed so long as there was confusion with respect to atoms and molecules; but since 1860 there has been continuous progress in this direction, though until very recently chemists had in their comparisons often made insufficient use of chemical units, as compared with the arbitrary unit of weight, the gram. As examples of this type of relationship we may mention: the heat capacities (specific heats) of gases; the molecular volume, the heat-change accompanying combustion, formation, or melting, particularly as applied to homologous series of organic compounds; the relation between constitution and color and other optical properties, etc.

Along with this went naturally the question of the properties of a substance as affected by mixture with another, of solutions in particular. The fact that the boiling-point of a solution is higher than that of the solvent itself had long been known, and measurements of the rise in boiling point caused by equal weights of dissolved material had been made; but it was not until 1884 that Ostwald pointed out that this rise is approximately the same, for any one solvent, when computed for equal numbers of molecules dissolved in the same amount of the solvent. The measurements had been mainly of solutions of a salt in water; but in 1886 Raoult extended the observations to other substances and stated what is now known as Raoult's law, which may be considered as the fundamental law formulating the dependence of the general properties of a perfect solution upon its composition; namely, the lowering of the vapor pressure of the solvent is proportional to the number of dissolved molecules per unit of solvent, or as now frequently phrased, the partial pressure of a component of a solution is proportional to its molar fraction, the molar fraction being defined as the ratio of the number of molecules of that component to the total number of molecules present. Soon thereafter van't Hoff gave the thermodynamic relationships between lowering of vapor pressure and raising of boiling-point, lowering of freezing-point, and osmotic pressure; by means of which any one of these may be deduced from another provided that certain constants characteristic of the solvent are known. It was then possible, from such measurements, to calculate the mole-

cular weight of the substance in solution; when this was done, many of the results were anomalous—in particular, the apparent molecular weight of a salt in solution in water was little more than half what one would expect from its formula.

Now it had long been known that certain classes of substances dissolved in water yield a solution which is a good conductor of electricity, and that aqueous solutions of other substances are poor conductors; the former class, called electrolytes by Faraday, comprises salts, acids and bases (alkalies), whereas the typical non-electrolyte is an organic substance such as sugar. And it was precisely these electrolytes which exhibited the anomalous molecular weight. To account for this anomaly Arrhenius propounded the theory of electrolytic dissociation, the basic idea of which is that the electrolytes, when dissolved in water, dissociate into two or more constituent particles, that these constituents are the ions, or carriers of electricity through the solution, and that each ion affects the general properties of the solution just as if it were an independent molecule. This theory is another landmark in the field of chemistry, for it has served to correlate and systematize a very large number of apparently diverse facts.

It would lead too far to go into the consequences and applications of the theory of ionization; how it enables us to choose the optimum conditions under which to carry out many analytical operations; how it leads to the view that acidity is determined by the actual concentration of hydrogen-ion (H^+), and basicity (alkalinity) by hydroxyl-ion (OH^-), etc. Its usefulness and importance in aiding us towards a real knowledge of aqueous solutions—a knowledge so essential to progress in many lines—is so great as to require no emphasis. And yet the theory is not completely satisfactory, there being still some outstanding anomalies, particularly in connection with the so-called strong electrolytes as typified by ordinary salts; but there is hope that these discrepancies will disappear with the growth of knowledge of electrochemistry.

The fundamental law of electrochemistry was discovered by Faraday prior to 1840, namely: that one unit of electricity transports one chemical equivalent of an ion, irrespective of voltage, temperature, concentration or other conditions. Later, it was established that these ions move independently of one another, and with characteristic velocities, facts which, with others, were satisfactorily coordinated by the theory of ionization; which in turn led to greatly improved control of practical electrochemical processes, such as electroplating. Again, it had long been known that an electromotive force is set up whenever there is a difference of any kind at two electrodes immersed in an electrolyte, and when two similar electrodes are placed in different solutions, or in solutions of the same substance at different concentrations. The next

step in advance was taken by Nernst, in 1889, who, from thermodynamical reasoning confirmed by direct experiment, deduced the relation between the electro-motive force and the ratio of effective concentration of the active ion in one solution to that in the other. Measurement of electromotive force, therefore, under appropriate conditions, yields independent information as to the effective concentration, or activity, of the ions. Nor is this the only application of this principle to the development of chemistry; for it also affords a measure of chemical affinity.

One of the characteristic phenomena accompanying a chemical change is an evolution or absorption of heat; in other words, the amount of heat contained by the reacting system changes with the chemical change. The measurement of this heat change, which may range from a large negative quantity through zero to a large positive quantity, is the province of thermo-chemistry. Our knowledge of these heats of reaction is largely due to Thomsen and to Berthelot, each of whom started from the supposition that the heat effect is a direct measure of relative affinity; and it was with this end in view that they carried out the very laborious work involved in these determinations. It is now clear that this supposition is erroneous, that the maximum work producible by a reaction, or its free energy, is a truer measure of affinity, the heat effect being an important factor in this maximum work or free energy. The systematic determination of the free energy of reactions, one of the most potent methods being the electrical method outlined above, is an outstanding task of modern chemistry, of consequence to the progress of the science as well as to industrial progress.

Graham, the discoverer in 1829 of the law relating the rate of diffusion of a gas to its density, later made experiments on the rate of diffusion of dissolved substances through animal membranes; this work led him to divide substances into two categories—the rapidly moving crystalloids, typified by salt, and the slow moving colloids, typified by gum arabic or gelatine. For a long time this distinction persisted, colloids being regarded as somewhat mysterious, rather messy, substances; and it was apparently considered a good explanation of some ill-understood phenomenon to attribute it, if possible, to a colloid. This whole matter received little systematic attention for forty years and only after 1900 did it become evident that we should not speak of a colloid as a distinct class of substances, but may speak only of the colloidal state. The characteristic phenomenon is the dispersion of one substance in another, the system being therefore heterogeneous; and the properties of the colloidal system depend upon the kind of particle, and upon their fineness,—in short, upon the nature and extent of the surface of separation of the two phases. In an outline on the present

scale one cannot go further into colloid chemistry, except to say that nearly everything remains to be done and that increased knowledge of the subject is fundamental to progress along many lines in biology and medicine, and is also of inestimable importance to all manner of industries, ranging from tanning to pottery.

Closely connected with this, since they also are surface effects, are the phenomena of adsorption and of catalysis, both known in more or less isolated instances for a long time, and both very ill understood. Their importance has been demonstrated recently, the former in connection with the provision of a satisfactory gas-mask, the latter as a means of making certain products—for instance, edible fats out of inedible oils,—in the fixation of atmospheric nitrogen, etc. And there is no question that both phenomena will be made use of increasingly, and that this increase will be accelerated as soon as we begin to understand the principles underlying these phenomena, a matter upon which we are still in the dark. Indeed, even as it is, extension of the use of catalytic methods is proceeding so rapidly that predictions are being made that we are entering upon what might be called a catalytic age in so far as the making of many chemical products is concerned.

As we have already noted, practically all chemical work, until very recently, had been carried out within a temperature range extending only from 0° up to 400° and at pressures ranging from atmospheric down to, say, 0.01 atmosphere. But the recent extension of these ranges has had so many practical consequences as to require some mention. This extension, though it hardly involves any important new chemical principle, has in a sense been equivalent to one, in that it has forced chemists to consider the subject more broadly and to remember that "ordinary conditions" are quite arbitrary in reference to the subject as a whole. To illustrate, the chemistry at the 1000° horizon, though subject to the same general principles, has to deal with only a small fraction of the compounds familiar to us at the 25° horizon, and is incomparably simpler; at the 2000° horizon it would be still simpler, and at still higher temperatures—as in many of the stars —the elements, at that temperature all gaseous, in place of being combined with one another, would probably be in part themselves dissociating.

Before 1845 Faraday had succeeded in liquefying, by cooling and compressing, many of the gases then known; but a few of the most common gases—viz., nitrogen, oxygen, hydrogen, carbon monoxide, nitric oxide, methane—resisted all his efforts, wherefore they were often alluded to as the "permanent gases." The clue was given in 1861 by Andrews, who showed that there is for each gas a critical temperature above which it cannot be liquefied by any pressure whatever;[14] and the reason for lack of success with the permanent gases was that the

lowest temperature employed had been above the critical point of those gases. With appreciation of this point and with improvements of technique, resulting in part from theory and in part from practice, success was finally achieved in all cases; all known gases have therefore now been liquefied, and there is only a difference in degree of "permanence" between hydrogen which condenses to liquid at 30° absolute and water vapor (steam) which condenses at 373° absolute. The main victories in conquering this region are given in the following table:

LIQUEFACTION OF THE "PERMANENT" GASES

Substance	Date when liquid first obtained	Observer	Liquid Critical Temperature C.	Liquid Critical Temperature abs.	Boiling Temperature C.	Boiling Temperature abs.	Freez'g Temp. C.	Freez'g Temp. abs.
Oxygen	1883	Wroblewski	—118°	155	—181°	92	—235	38
Nitrogen	1883	Wroblewski	—146	127	—195	78	—215	58
Hydrogen	1898	Dewar	—243	30	—252	21	—248	17
Helium	1908	Onnes	—268	5	—269	4		2.5

To this may be added that liquid air was first obtained by Wroblewski in 1885, was available for research purposes in 1891, and since 1895, with the development of the commercial machine for producing it, has become an industry; it is now indispensable to several lines of work—for instance, wherever very low pressures are required. Incidentally, too, its development resulted in the invention of the vacuum-jacketed, or Dewar, tube which is now a necessary tool in all work at low temperatures and a convenience to the community generally.

With the command of low temperatures, it is now possible to make accurate measurement, e. g. of specific heats, at temperatures not so far removed from the absolute zero. And there is reason to believe that this type of work is going to furnish very valuable information on some moot questions; for instance, on the entropy of substances at the lowest temperatures and on the applicability of the Nernst heat theorem, called by some the third law of thermodynamics—questions which bear a very intimate relation to the problem of the nature of chemical affinity.

Apart from mainly qualitative work, such as that of Moissan with his arc-furnace on the carbides, little accurate high-temperature work was done until about 1900. In the meantime methods of control and measurement have been developed to such an extent that many types of measurement may be made just as accurately at 1000° as at 100°. This has enabled many equilibria, both homogeneous (usually in gas systems) and heterogeneous (that is, essentially solubilities), to be determined carefully over a wide range of temperature. Such knowledge is essential for many purposes, both practical and theoretical—from the nature of combustion to the constitution of alloys and the mode of formation of minerals and rocks. Very recently high tem-

[14]Though, as we now know, it may be solidified by application of sufficient pressure at temperatures higher than the critical end-point of the liquid.

peratures have been coupled with minimal pressures in experimental work on electron emission and related topics; but this is at the moment usually considered a part of the domain of physics, which has not yet received adequate attention from a chemical point of view. In the field of high pressures, as in that of high temperatures, recent technical progress has made it possible to follow many types of changes with as high accuracy at a pressure of 10,000 atmospheres (i. e. 150,000 pounds to the square inch) as at 10 atmospheres. This is bringing to light phenomena hitherto unsuspected; thus, when the whole range is considered, it appears to be the rule, rather than the exception, that a substance when solidified exists in more than one crystalline form, each stable within a definite range of temperature and pressure. As an instance of this, there are in addition to ordinary ice, at least four other forms of crystalline water, stable at high pressure; and under increasing high pressure the freezing temperature of water steadily rises until at, for instance, a pressure of 20,000 atm. it freezes about 73° (centigrade) higher than its ordinary freezing point.

The phenomena observed at high and low temperatures and at high and low pressures all illustrate the fact that chemistry should not be looked upon as a collection of isolated things which can be manipulated in a sort of magical way, but is to be thought of as, in a sense, almost a continuum all parts of which are subject to definite laws, still incompletely elucidated; the relative behavior of all substances being controlled by these laws in the same sense as the relative motions of the heavenly bodies are controlled by the law of gravitation.

In this brief sketch of the development of chemical science, many things must remain unmentioned. Yet it must not be supposed that these things are intrinsically unimportant; indeed an explanation of some puzzling phenomenon may arise out of work in another field, apparently entirely unrelated, each advance in knowledge of any field being that much wrested from the domain of ignorance, and reacting in favor of advances at other points of the line. In particular it has not been practicable to mention the several branches of applied chemistry, for instance, the study of the substances and reactions involved in life-processes, with its remarkable advance within the last few years, which would require a chapter to itself; or even analytical chemistry, an essential branch of the subject, which develops with each development of principle, and is to be regarded as including all methods of analysis and not merely the semi-traditional methods applied to a somewhat restricted group of salts of certain metallic bases. The growth of the whole subject-matter may perhaps be gauged from the fact that the 1920 volume of Chemical Abstracts, which gives merely brief abstracts of papers of interest to chemists published within the year, contains more than 4,000 pages, and that the index to this volume alone

will cover more than 600 pages closely printed in double column. From this it is obvious that, even though a large proportion of these papers contain little of real value, one cannot keep abreast of advances in the whole subject but can only hope to have a general knowledge of principles and to acquire a special knowledge of some restricted field.

These principles of chemical science are of its essence and constitute its philosophy; only with development of this philosophy will it be possible to progress in the correlation and systematization of the multitudinous facts of chemistry. The progress of this philosophy, which indeed demands the services of the physicist as much as those of the chemist, is obliterating the line of demarcation between these two sciences. Initially physics dealt mainly with changes which affect matter independently of its composition, whereas chemistry was concerned mainly with the change of composition; but the physicist and chemist came to meet on common ground for the reason that the quantitative measures of most of the so-called physical properties are intimately connected with the constitution of the substance. And it may be said that the recent very significant advances—dating, say from the discovery of the X-rays—concern the chemist just as much as the physicist, and that each of them should be conversant with the general mode of thought of the other. Indeed the several sciences have in the past been too far apart from one another, and we should now seek increased co-operation, for it is precisely in the boundary regions between them that the most valuable advances in the immediate future will be made.

THE BIOLOGY OF DEATH—VI. EXPERIMENTAL STUDIES ON THE DURATION OF LIFE[1]

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1. Inheritance of Duration of Life in Drosophila

IN the last paper there was presented indubitable proof that inheritance is a major factor in determining the duration of life in man. The evidence, while entirely convincing and indeed in the writer's opinion critically conclusive, must be, in the nature of the case, statistical in its nature. Experimental inquiries into the duration of human life are obviously impossible. Public opinion frowns upon them in the first place, and even if this difficulty were removed man would furnish poor material for the experimental study of this particular problem because he lives too long. It is always important, however, as a general principle, and particularly so in the present instance, to check one's statistical conclusions by independent experimental evidence. This can be successfully done, when one's problem is longevity, only by choosing an animal whose life-span relative to that of man is a short one, and in general the briefer it is the better suited will the animal be for the purpose.

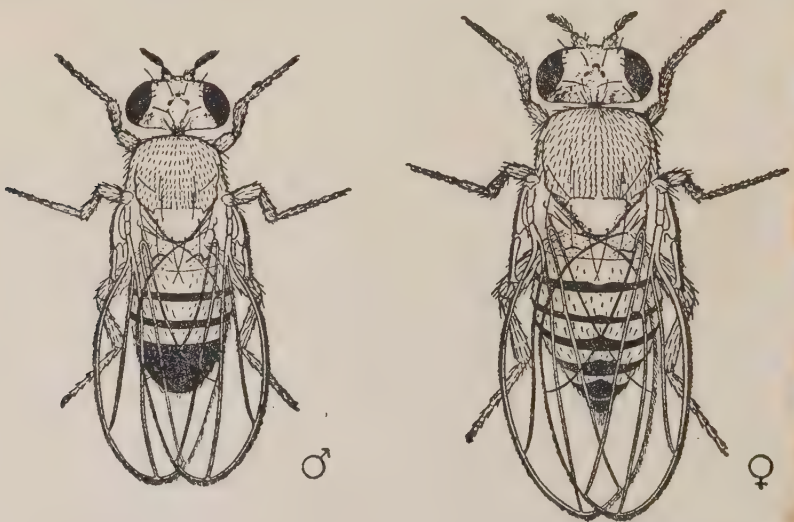

FIG. 1. MALE AND FEMALE FRUIT FLY (*Drosophila melanogaster*). (From Morgan)

[1] Papers from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, Johns Hopkins University, No. 33.

An organism which rather completely fulfils the requirements of the case, not only in respect of the shortness of the life span, but also in other ways, such as ease of handling, feeding, housing, etc., is the common "fruit" or "vinegar" fly, *Drosophila melanogaster*. This creature, which every one has seen hovering about bananas and other fruit in fruit shops, has lately attained great fame and respectability as a laboratory animal, as a result of the brilliant and extended investigations of Morgan and his students upon it, in an analysis of the mechanism of heredity. *Drosophila* is a small fly, perhaps one fourth as large as the common house fly. It has striking red eyes, a brownish body, and wings of length and form varying in different strains. It lives normally on the surface of decaying fruit of all sorts, but because of a more or less well marked preference for banana it is sometimes called the "banana" fly. While it lives on decaying fruit surfaces its food is mainly not the fruit itself, but the yeast which is always growing in such places.

The life cycle of the fly is as follows: The egg laid by the female on some fairly dry spot on the food develops in about 1 day into a larva. This larva or maggot squirms about and feeds in the rich medium in which it finds itself for about 3 to 4 days and then forms a pupa. From the pupa the winged imago or adult form emerges in about 4 or 5 days. The female generally begins to lay eggs within the first 24 hours after she is hatched. So then we have about 8 to 10 days as the minimum time duration of a generation. The whole cycle from egg to egg, at ordinary room temperature, falls within this 10-day period with striking accuracy and precision.

The duration of life of the adult varies in an orderly manner from less than 1 day to over 90 days. The span of life of *Drosophila* quantitatively parallels in an extraordinary way that of man, with only the difference that life's duration is measured with different yardsticks in the two cases. Man's yardstick is one *year* long, while *Drosophila's* is one *day* long. A fly 90 days old is just as decrepit and senile, for a fly, as a man 90 years old is in human society.

This parallelism in the duration of life of *Drosophila* and man is well shown in Fig. 2, which represents a life table for adult flies of both sexes. The survivorship, or l_x figures, are the ones plotted. The curves deal only with flies in the adult or imago stage, after the completion of the larval and pupal periods. The curve is based upon 3,216 female and 2,620 male flies, large enough numbers to give reliable and smooth results. We note at once that in general the curve has the same form as the corresponding l_x curve from human mortality tables. The most striking difference is in the absence from the fly curves of the heavy infant mortality which characterizes the human curve. There is no specially sharp drop in the curve at the beginning of the life cycle,

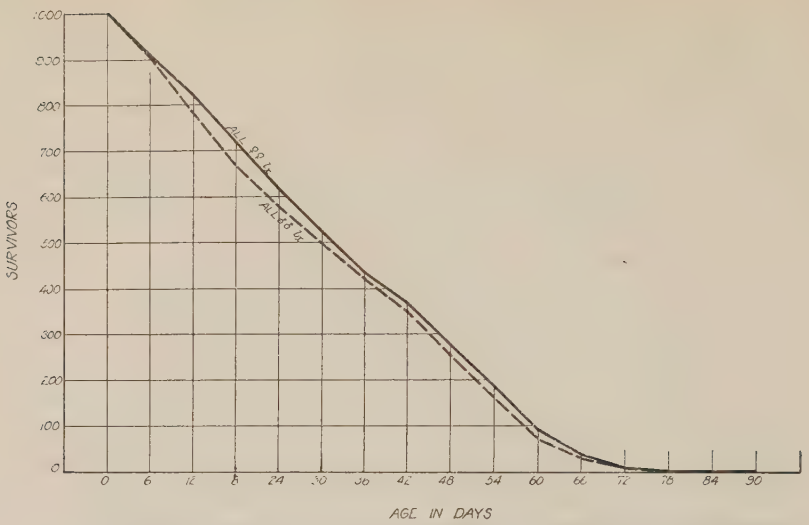

FIG. 2. LIFE LINES FOR *Drosophila melanogaster*, SHOWING THE SURVIVORS AT DIFFERENT AGES OUT OF 1000 BORN AT THE SAME TIME

such as has been seen in the l_x curve for man in an earlier paper in this series. This might at first be thought to be accounted for by the fact that the curve begins after the infantile life of the fly, but it must be remembered that the human l_x line begins at birth, and no account is taken of the mortality *in utero*. Really the larval and pupal stages of the fly correspond rather to the foetal life of a human being than to the infant life, so that one may fairly take the curves as covering comparable portions of the life span in the two cases and reach the conclusion that there is not in the fly an especially heavy incidence of mortality in the infant period of life, as there is in man. The explanation of this fact is, without doubt, that the fly when it emerges from the pupal stage is completely able to take care of itself. The baby is, on the contrary, in an almost totally helpless condition at the same relative age.

It is further evident that at practically all ages in *Drosophila* the number of survivors at any given age is higher among the females than among the males. This, it will be recalled, is exactly the state of the case in human mortality. The speed of the descent of the *Drosophila* curve slows off in old age, just as happens in the human life curve. The rate of descent of the curve in early middle life is somewhat more rapid with the flies than in the case of human beings, but as will presently appear there are some strains of flies which give curves almost identical in this respect with the human mortality curves. In the life curves of Figure 2, all different degrees of inherited or constitutional variation in longevity are included together. More accurate pictures of the true state of affairs will appear when we come, as we presently shall, to deal with groups of individuals more homogeneous in respect of their hereditary constitutions.

Having now demonstrated that the incidence of mortality is in general similar in the fly *Drosophila* to what it is in man, with a suitable change of unit of measure, we may proceed to examine some of the evidence regarding the inheritance of duration of life in this organism. The first step in such an examination is to determine what degree of natural variation of an hereditary sort exists in a general fly population in respect of this characteristic. In order to do this it is necessary to isolate individual pairs, male and female, breed them together and see whether, between the groups of offspring so obtained, there are genetic differences in respect of duration of life which persist through an indefinite number of generations. This approaches closely to the process called by geneticists the testing of pure lines. In such a process the purpose is to reduce to a minimum the *genetic* diversity which can possibly be exhibited in the material. In a case like the present, the whole amount of genetic variation in respect of duration of life which can appear in the offspring of a single pair of parents is only that which can arise by virtue of its prior existence in the parents themselves individually, and from the combination of the germinal variation existing in the two parents one with another. We may call the offspring, through successive generations, of a single pair of parents a line of descent. If, when kept under identical environmental conditions such lines exhibit widely different average durations of life, and if these differences reappear with constancy in successive generations, it may be justly concluded that the basis of these differences is hereditary in nature, since by hypothesis the environment of all the lines is kept the same. In consequence of the environmental equality whatever differences do appear must be inherently genetic.

The manner in which these experiments are performed may be of interest. An experiment starts by placing two flies, brother and sister, selected from a stock bottle, together in a half-pint milk bottle. At the bottom of the bottle is a solidified, jelly-like mixture of agar-agar and boiled and pulped banana. On this is sown as food some dry yeast. A bit of folded filter paper in the bottle furnishes the larvae opportunity to pupate on a dry surface. About ten days after the pair of flies have been placed in this bottle fully developed offspring in the imago stage begin to emerge. The day before these offspring flies are due to appear, the original parent pair of flies are removed to another bottle precisely like the first, and the female is allowed to lay another batch of eggs over a period of about nine days. In the original bottle there will be offspring flies emerging each day, having developed from the eggs laid by the mother on each of the successive days during which she was in the bottle. Each morning the offspring flies which have emerged during the preceding twenty-four hours are transferred to a small bottle. This has, just as the larger one, food material at the

bottom and like the larger one is closed with a cotton stopper. All of the offspring flies in one of these small bottles are obviously of the same age, because they were born at the same time, using this term "born" to denote emergence from the pupal stage as imagines. Each following day these small bottles are inspected. Whenever a dead fly is found it is removed and a record made in proper form of the fact that its death occurred, and its age and sex are noted. Finally, when all the flies in a given small bottle have died that bottle is discarded, as the record of the duration of life of each individual is then complete. All the bottles are kept in electric incubators at a constant temperature of 25° C., the small bottles being packed for convenience in wire baskets. All have the same food material, both in quality and quantity, so that the environmental conditions surrounding these flies during their life may be regarded as substantially constant and uniform for all.

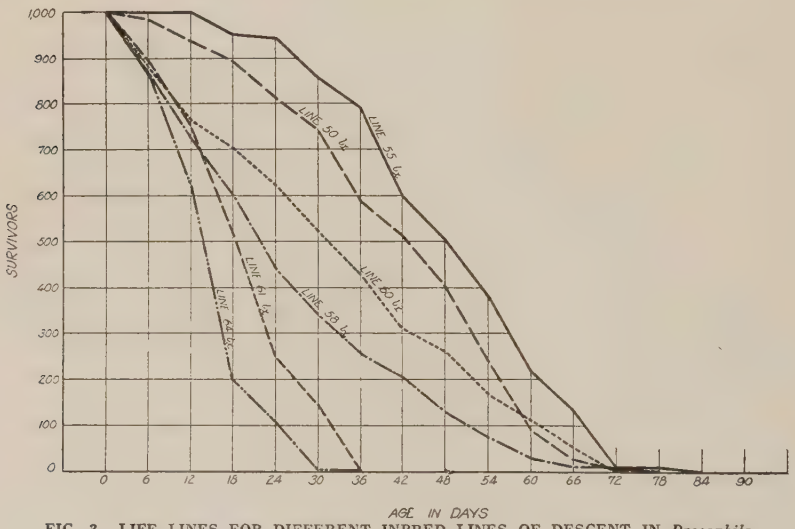

FIG. 3. LIFE LINES FOR DIFFERENT INBRED LINES OF DESCENT IN *Drosophila*

Fgure 3 shows the survival frequency, or l_x line of a life table, for six different lines of *Drosophila*, which have been bred in my laboratory. Each line represents the survival distribution of the offspring of a single brother and sister pair mated together. In forming a line a brother and sister are taken as the initial start because by so doing the amount of genetic variation present in the line at the beginning is reduced to the lowest possible minimum. It should be said that in all of the curves in Figure 3 both male and female offspring are lumped together. This is justifiable for illustrative purposes because of the small difference in the expectation of life at any age between the sexes. The line of descent No. 55 figured at the top of the diagram gives an l_x line extraordinarily like that for man, with the exception of

the omission of the sharp drop due to infantile mortality at the beginning of the curve. The extreme duration of life in this line was 81 days, reached by a female fly. The l_x line drops off very slowly until age 36 days. From that time on the descent is more rapid until 72 days of age are reached when it slows up again. Lines 50, 60, and 58 show l_x curves all descending more rapidly in the early part of the life cycle than that for line 55, although the maximum degree of longevity attained is about the same in all of the four first curves. The general shape of the l_x curves changes however, as is clearly seen if we contrast line 55 with line 58. The former is concave to the base through nearly the whole of its course, whereas the l_x curve for line 58 is convex to the base practically throughout its course. While, as is clear from the diagram, the maximum longevity attained is about the same for all of these upper four lines, it is equally obvious that the mean duration of life exhibited by the lines falls off as we go down the diagram. The same process, which is in operation between lines 55 and 58, is continued in an even more marked degree in lines 61 and 64. Here not only is the descent more rapid in the early part of the l_x curve, but the maximum degree of longevity attained is much smaller, amounting to about half of that attained in the other four lines. Both lines 61 and 64 tend to show in general a curve convex to the base, especially in the latter half of their course.

Since each of these lines of descent continues to show through successive generations, for an indefinite time, the same types of mortality curves and approximately the same average durations of life, it may safely be concluded that there are well marked hereditary differences in different strains of the same species of *Drosophila* in respect of duration of life. Passing from the top to the bottom of the diagram the average expectation of life is reduced by about two-thirds in these representative curves. For purposes of experimentation, each one of these lines of descent becomes comparable to a chemical reagent. They have a definitely fixed standard duration of life, each peculiar to its own line and determined by the hereditary constitution of the individual in respect of this character. We may, with entire justification, speak of the flies of line 64 as hereditarily and permanently short-lived, and those of line 55 as hereditarily long-lived.

Having established so much, the next step in the analysis of the mode of inheritance of this character is obviously to perform a Mendelian experiment by crossing an hereditarily short-lived line with a hereditarily long-lived line, and follow through in the progeny of successive generations the duration of life. If the character follows the ordinary course of Mendelian inheritance, we should expect to get in the second offspring generation a segregation of different types of flies in respect of their duration of life.

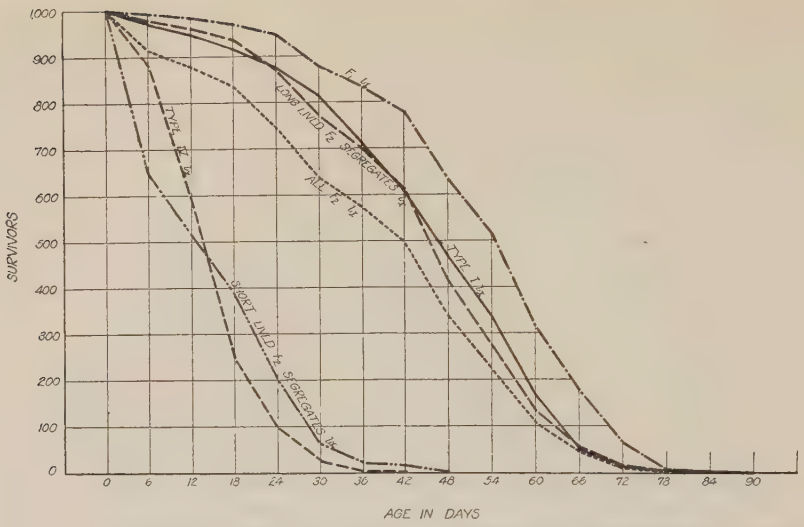

FIG. 4. LIFE LINES SHOWING THE RESULT OF MENDELIAN EXPERIMENTS ON THE DURATION OF LIFE IN *Drosophila*. Explanation in text

Figure 4 shows the result of such Mendelian experiment performed on a large scale. In the second line from the top of the diagram, labelled "Type I l_x," we see the mortality curve for an hereditarily long-lived pure strain of individuals. At the bottom of the diagram the "Type IV l_x" line gives the mortality curve for one of our hereditarily short-lived strains. Individuals of Type I and Type IV were mated together. The result in the first offspring hybrid generation is shown by the line at the top of the diagram marked "F_1 l_x." The F_1 denotes that this is the mortality curve of the *first filial generation* from the cross. It is at once obvious that these first generation hybrids have a greater expectation of life at practically all ages than do either of the parent strains mated together to produce the hybrids. This result is exactly comparable to that which has for some time been known to occur in plants, from the researches particularly of Professor E. M. East of Harvard University with maize. East and his students have worked out very thoroughly the cause of this increased vigor of the first hybrid generation and show that it is directly due to the mingling of different germ plasms.

The average duration of life of the Type I original parent stock is 44.2 ± .4 days. The average duration of life of the short-lived Type IV flies is 14.1 ± .2 days, or only about one third as great as that of the other stock. The average duration of life of the first hybrid generation shown in the F_1 l_x line is 51.5 ± .5 days. So that there is an increase in average duration of life in the first hybrid generation, over that of the long-lived parent, of approximately 7 days. In estimating the significance of this, one should remember that a day in the life of a

fly corresponds, as has already been pointed out, almost exactly to a year in the life of a man.

When individuals of the first hybrid generation are mated together to get the second, or F_2 hybrid generation we get a group of flies which, *if taken all together*, give the mortality curve shown in the line at about the middle of the diagram, labelled "All F_2 l_x." It, however, tells us little about the mode of inheritance of the character if we consider all the individuals of the second hybrid generation together, because really there are several kinds of flies present in this second hybrid generation. There are sharply separated groups of long-lived flies and of short-lived flies. These have been lumped together to give the "All F_2 l_x" line. If we consider separately the long-lived second generation group and the short-lived second generation group we get the results shown in the two lines labelled "Long-lived F_2 Segregates l_x," and "Short-lived F_2 Segregates l_x." It will be noted that the long-lived F_2 segregates have a mortality curve which almost exactly coincides with that of the original parent Type I stock. In other words, in the second generation after the cross of the long-lived and short-lived types a group of animals appears having almost identically the same form of mortality curve as that of one of the original parents in the cross. The mean duration of life of this long-lived second generation group is 43.3 $\pm$ .4 days, while that of the original long-lived stock was 44.2 $\pm$ .4 days. The short-lived F_2 segregates shown at the bottom of the diagram give a mortality curve essentially like that of the original short-lived parent strain. The two curves wind in and about each other, the F_2 flies showing a more rapid descent in the first half of the curve and a slower descent in the latter half. In general, however, the two are very clearly of the same form. The average duration of life of these short-lived second generation segregates is 14.6 $\pm$ .6 days. This, it will be recalled, is almost identically the same average duration of life as the original parent Type IV gave, which was 14.1 $\pm$ .2 days.

It may occur to one to wonder how it is possible to pick out the long-lived and short-lived segregates in the second generation. This is done by virtue of the correlation of the duration of life of these flies with certain external bodily characters, particularly the form of the wings, so that this arrangement of the material can be made with perfect ease and certainty.

These results show in a clear manner that duration of life, in *Drosophila* at least, is inherited essentially in accordance with Mendelian laws, thus fitting in with a wide range of other physical characters of the animal which have been thoroughly studied, particularly by Morgan and his students. Such results as these just shown constitute the best kind of proof of the essential point which we are getting at—namely, the fact that duration of life is a normally inherited character.

I do not wish at this time to go into any discussion of the details of the Mendelian mechanism for this character, in the first place, because it is too complicated and technical a matter for discussion here,[2] and in the second place, because the investigations are far from being completed yet. I wish here and now merely to present the demonstration of the broad general fact that duration of life is inherited in a normal Mendelian manner in these fly populations. The first evidence that this was the case came from some work of Dr. R. R. Hyde with *Drosophila* some years ago. The numbers involved in his experiment, however, were much smaller than those of the present experiments, and the preliminary demonstration of the existence of pure strains relative to duration of life in *Drosophila* was not undertaken by him. Hyde's results and those here presented are entirely in accord.

With the evidence which has now been presented regarding the inheritance of life in man and in *Drosophila* we may let that phase of the subject rest. The evidence is conclusive of the broad fact, beyond any question I think, coming as it does from such widely different types of life, and arrived at by such totally different methods as the statistical, on the one hand, and the experimental, on the other. We may safely conclude that the primary agent concerned in the winding up of the vital clock, and by the winding determining primarily and fundamentally how long it shall run, is heredity. The best insurance of longevity is beyond question a careful selection of one's parents and grandparents.

2. Bacteria and Duration of Life in Drosophila

But clocks may be stopped in other ways than by running down. It will be worth while to consider with some care a considerable mass of most interesting, and in some respects even startling, experimental data, regarding various ways in which longevity may be influenced by external agents. Since we have just been considering *Drosophila* it may be well to consider the experimental evidence regarding that form first. It is an obviously well-known fact that bacteria are responsible in all higher organisms for much organ breakdown and consequent death. An infection of some particular organ or organ system occurs, and the disturbance of the balance of the whole so brought about finally results in death. But is it not possible that we overrate the importance of bacterial invasion in determining, in general and in the broadest sense, the average duration of life? May it not be that when an organ system breaks down under stress of bacterial toxins, that it is in part at least, perhaps primarily, because for internal organic reasons the resistance of that organ system to bacterial invasion has normally

[2] Full technical details and all the numerical data regarding these and other *Drosophila* experiments referred to in this and other papers in the series, will shortly be published elsewhere.

and naturally reached such a low point that its defenses are no longer adequate? All higher animals live constantly in an environment far from sterile. Our mouths and throats harbor pneumonia germs much of the time, but we do not all or always have pneumonia. Again it may fairly be estimated that of all persons who attain the age of 35, probably at least 95 per cent. have at some time or other been infected with the tubercle bacillus, yet only about one in ten breaks down with active tuberculosis.

What plainly is needed in order to arrive at a just estimate of the relative influence of bacteria and their toxins in determining the average duration of life is an experimental inquiry into the effect of a bacteria-free, sterile mode of life. Metchnikoff has sturdily advocated the view that death in general is a result of bacterial intoxication. Now a bacteria free existence is not possible for man. But it is possible for certain insects, as was first demonstrated by Bogdanow, and later confirmed by Delcourt and Guyenot. If one carefully washes either the egg or the pupa of *Drosophila* for 10 minutes in a strong antiseptic solution, say 85 per cent. alcohol, he will kill any germs which may be upon the surface. If the bacteria-free egg or pupa is then put into a sterile receptacle, containing only sterile food material and a pure culture of yeast, development will occur and presently an adult imago will emerge. Adult flies raised in this way are sterile. They have no bacteria inside or out. Normal healthy protoplasm is normally sterile, so what is inside the fly is bound to be sterile on that account, and by the use of the antiseptic solution what bacteria were on the outside have been killed.

The problem now is, how long on the average do such sterile specimens of *Drosophila* live in comparison with the ordinary fly, which is throughout its adult life as much beset by bacteria relatively as is man himself, it being premised that in both cases an abundance of proper food is furnished and that in general the environmental conditions other than bacterial are made the same for the two sets? Fortunately, there are some data to throw light upon this question from the experiments of Loeb and his associate Northrop on the duration of life in this form, taken in connection with experiments in the writer's laboratory.

Loeb and Northrop show that a sample of 70 flies, of the *Drosophila* with which they worked, which were proved by the most careful and critical of tests to have remained entirely free of bacterial contamination throughout their lives, exhibited, when grown at a constant temperature of 25° C. *an average duration of life of 28.5 days.* In our experiments 2620 male flies, of all strains of *Drosophila* in our cultures taken together, thus giving a fair random sample of genetically the whole *Drosophila* population, gave an average duration of life at the same constant temperature of 25° C. of 31.3 $\pm$ .3 days, and 3216

females under the same temperature lived an average of 33.0 ± .2 days. These were all non-sterile flies, subject to all the bacterial contamination incident to their normal laboratory environment, which we have seen to be a decaying germ-laden mass of banana pulp and agar. It is thought to be fairer to compare a sample of a general population with the Loeb and Northrop figures rather than a pure strain because probably their *Drosophila* material was far from homozygous in respect of the genes for duration of life.

The detailed comparisons are shown in Table 1.

TABLE 1

Average duration of life of Drosophila in the imago stage at 25° C.

Experimental group	Mean duration of life in days	Number of flies
Sterile (Loeb and Northrop)	28.5	70
Non-sterile, males, all genetic lines (Pearl)	31.3	2620
Non-sterile, females, " " " "	33.0	3216
Non-sterile, both sexes, " " " "	32.2	5836
Difference in favor of non-sterile	3.7	....
Probable error of difference about	± 1.0	....

We reach the conclusion that bacteria-free *Drosophila* live no longer on the average, and indeed perhaps even a little less long, under otherwise the same constant environmental conditions, than do normal non-sterile—indeed germ-laden—flies. This result is of great interest and significance. It emphasizes in a direct experimental manner that in a *broad biological sense* bacteria play but an essentially accidental role in determining length of the span of life in comparison with the influence of heredity. There is every reason to believe that if the same sort of experiment were possible with man as material, somewhat the same sort of result in broad terms would appear.

3. Poverty and Duration of Life

But we must take care lest we seem to convey the impression that no sort of environmental influence can affect the average duration of life. Such a conclusion would be manifestly absurd. Common sense tells us that environmental conditions in general can, and under some circumstances, do exert a marked influence upon expectation of life. A recent study of great interest and suggestiveness, if perhaps some lack of critical soundness, by the eminent Swiss statistician, Hersch, well illustrates this. Hersch became interested in the relation of poverty to mortality. He gathered data from the 20 arrondissements of the City of Paris in respect of the following points, among others:

a. Percentage of families not paying a personal property tax.
b. Death rate per 1000 from all causes.
c. Still births per 1000 living births.

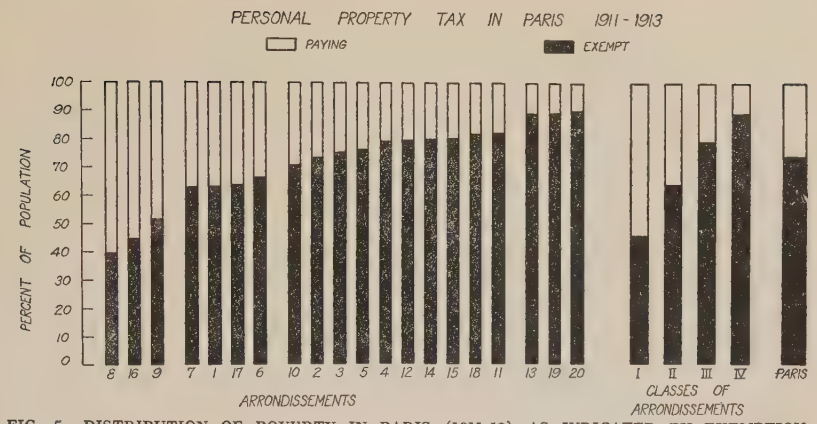

FIG. 5. DISTRIBUTION OF POVERTY IN PARIS (1911-13) AS INDICATED BY EXEMPTION FROM PERSONAL PROPERTY TAX. (After Hersch)

Figure 5 shows in the black the percentage of families too poor to have any personal property tax assessed, first for each arrondissement separately, then at the right in broader bars for the four groups of arrondissements separated by wider spaces in the detailed diagram, and finally for Paris as a whole. It will be seen that the poverty of the population, measured by the personal property yardstick, is least at the lefthand end of the diagram, where the smallest percentages of families are exempted from the tax, and greatest at the right hand end, where scarcely any of the population is well enough to do to pay this tax.

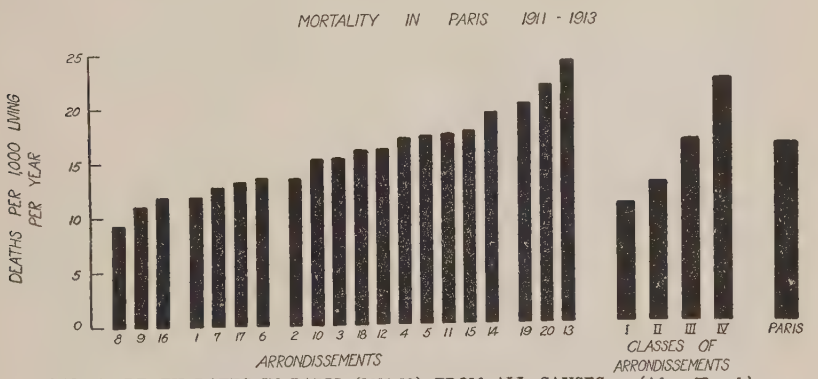

FIG. 6. DEATH RATES IN PARIS (1911-13) FROM ALL CAUSES. (After Hersch)

Figure 6 shows the death rates from all causes for the same arrondissements and the same groups. It is at once apparent that the black bars in this group run in a parallel manner to what they did in the preceding one. The poorest districts have the highest death rates, the richest districts the lowest death rates, and districts intermediate in respect of poverty are also intermediate in respect of mortality. On the face of the evidence there would seem to be here complete proof of

the overwhelmingly important influence upon duration of life of degree of poverty, which is perhaps the most potent single environmental factor affecting civilized man to-day. But, alas, pitfalls proverbially lurk in statistics. Before we can accept this so alluring result and go along with our author to his final somewhat stupendous conclusion that if there were no poverty the death rate from certain important causes, as for example tuberculosis, would forthwith become *zero*, we must exercise a little inquisitive caution. What evidence is there that the inhabitants of the districts showing a high poverty rate are not *biologically* as well as economically differentiated from the inhabitants of districts with a low poverty rate? And again what is the evidence that it is not such biological differentiation rather than the economic which determines the death rate differences in the two cases? Unfortunately, our author gives us no whit of evidence on these obviously so important points. He merely assumes, because of the facts shown, that if some omnipotent spook were to transpose all the inhabitants of the Menilmontant arrondissement to the Elysee arrondissement, and *vice versa* for example, and were to permit each group to annex the worldly goods of the dispossessed group, then the death rates would be forthwith interchanged. There is no real evidence that any such result would follow at all. Probably from what we know from more critical studies than this of the relation of social and economic conditions to mortality, each group would exhibit under the new circumstances a death rate not far different from what it had under the old conditions. One can not shake in the slightest degree from its solidly grounded foundation the critically determined fact of the paramount importance of the hereditary factor in determining rates of mortality, which have been summarized in this and the preceding paper, by any such evidence as that of Hersch.

TABLE 2

Still births in Paris (1911-13) *by classes of arrondissements* (*Hersch*)

Classes of Arrondissements	Absolute figures		Still births per 100 living births
	Still births	Living births	
I	1,004	12,313	8.2
II	1,390	19,998	7.0
III	7,279	82,821	8.8
IV	3,024	30,853	9.8
Paris	12,679	145,985	8.7

This, indeed, he himself finds to be the fact when he considers the extremely sensitive index of hereditary biological constitution furnished by the still-birth rate. Table 2 gives the data. We see at once that there is no such striking increase in the total mortality as we pass from

the richest class of districts, as was shown in the death rate from all causes. Instead there is practically no change, certainly none of significance, as we pass from one class of districts to another. The rate is 8.2 per 100 living births in the richest class and 9.8 in the poorest.

4. Experiments on Temperature and Duration of Life

Altogether it is plain that we need another kind of evidence than the simple unanalyzed parallelism which Hersch demonstrates between poverty and the general death rate if we are to get any deep understanding of the influence of environmental circumstances upon the duration of life or the general death rate. We shall do well to turn again to the experimental method. About a dozen years ago Loeb,

> starting from the idea that chemical conditions in the organisms are one of the main variables in this case, raised the question whether there was a definite coefficient for the duration of life and whether this temperature coefficient was of the order of magnitude of that of a chemical reaction. The first experiments were made on the unfertilized and fertilized eggs of the sea urchin and could only be carried out at the upper temperature limits of the organism, since at ordinary temperatures this organism lives for years. In the upper temperature region the temperature coefficient for the duration of life was very high, probably on account of the fact that at this upper zone of temperature death is determined by a change of the nature of a coagulation or some other destructive process. Moore, at the suggestion of Loeb, investigated the temperature coefficient for the duration of life for the hydranth of a tubularian at the upper temperature limit and found that it was of the same order of magnitude as that previously found for the sea urchin egg. In order to prove that there is a temperature coefficient for the duration of life throughout the whole scale of temperatures at which an organism can live experiments were required on a form whose duration of life was short enough to measure the duration of life even at the lowest temperature.

A suitable organism was found in *Drosophila.* This was grown under aseptic conditions, as already described. The general results are shown in Table 3.

TABLE 3

Effect of temperature on duration of life of Drosophila.
(After Loeb and Northrop)

Temperature	Duration (in days) of			
	Larval stage	Pupal stage	Life of imago	Total duration of life from egg to death
°C				
10	57	Pupae die	120.5	$177.5 + x$
15	17.8	13.7	92.4	123.9
20	7.77	6.33	40.2	54.3
25	5.82	4.23	28.5	38.5
27.5	(4.15)	3.20	....	....
30	4.12	3.43	13.6	21.15

From this table it is seen that at the lowest temperature the duration of life is longest, and the highest temperature shortest. Cold slows up the business of living for the fly. Heat hastens it. One gathers, from the account which Loeb and Northrop give of the work, that at low temperature the flies are sluggish and inactive in all three developmental stages and perhaps live a long time because they live slowly. At high temperatures, on the other hand, the fly is very active and lives its life through quickly at the "pace that kills." These results are exactly comparable to the effect of a regular increase of temperature upon a chemical reaction. Indeed, Loeb and Northrop consider that their results prove that

> With a supply of proper and adequate food the duration of the larval stage is an unequivocal function of the temperature at which the larvae are raised, and the temperature coefficient is of the order of magnitude of that of a chemical reaction, i. e., about 2 or more for a difference of 10° C. It increases at the lower and is less at the higher temperatures. The duration of the pupal stage of the fly is also an unequivocal function of the temperature and the temperature coefficient is for each temperature practically identical with that for the larval stage. The duration of life of the imago is, with proper food, also an unequivocal function of the temperature and the temperature coefficient for the duration of life is within the normal temperature limits approximately identical with that for the duration of life of the larva and pupa.

How are these results to be reconciled with the previous finding that heredity is a primary factor in the determination of duration of life of *Drosophila?* We have here, on first impression at least, an excellent example of what one always encounters in critical genetic investigations: the complementary relations of heredity and environment. In our experiments a general mixed population of *Drosophila* kept under *constant environment* was shown to be separable by selection into a number of very diverse strains in respect of duration of life. In Loeb and Northrop's experiments a general mixed population of *Drosophila,* but of presumably *constant genetic constitution,* at least approximately such, throughout the experiment, was shown to exhibit changes of duration of life with changing environments. It is the old familiar deadlock. Heredity constant plus changing environment equals diversity. Environment constant plus varying hereditary constitution also equals diversity.

Can we penetrate no farther than this into the matter? I think in the present case we can. In Loeb and Northrop's experiments, temperature and duration of life were not the only two things that varied. The different temperature groups also differed from each other—*because* of the temperature differences to be sure but not less really—in respect of general metabolic *activity,* expressed in muscular movement and every other way. In the genetic experiments metabolic

activity was substantially equal in all the hereditarily different lines. The idea suggests itself, both on *a priori* grounds and also upon the basis of certain experimental data presently to be in part reviewed, that possibly duration of life may be an implicit function of only the two variables

a. Genetic constitution
b. Rate of metabolic activity.

The functional relations of metabolic activity with temperature, food, light and other environmental factors are all well known. For present purposes we do not need to go into the question of their exact form. The essential point is that all these environmental factors stand in definite functional relations to rate of metabolic activity, and do not so stand in relation to genetic constitution. Genetic constitution is not a function of the environment, but is for any individual a constant, and only varies between individuals.

This may be thought merely to be an involved way of saying what one knows *a priori;* namely, that duration of life, in general and in particular, depends only upon heredity and environment. So in one sense it is. But the essential point I would make here is that the *manner in which the environmental forces (of sub-lethal intensity, of course) chiefly act in determining duration of life appears to be by changing the rate of metabolism of the individual.* Furthermore one would suggest, on this view, that what heredity does in relation to duration of life is chiefly *to determine, within fairly narrow limits, the total energy output which the individual can exhibit in its life time.* This limitation is directly brought about presumably through two general factors; viz, (a) the kind or quality of material of which this particular vital machine is built, and (b) the manner in which the parts are put together or assembled. Both of these factors are, of course, expressions of the extent and character of the processes of organic evolution which have given rise to this particular species about which we may be talking in a particular instance.

There is some direct experimental evidence, small in amount to be sure, but exact and pertinent, to the effect that the duration of life of an animal stands in inverse relation to the total amount of its metabolic activity, or put in other words, to the work, in the sense of theoretical mechanics, that it *as a machine* does during its life. Slonaker kept 4 albino rats in cages like the old fashioned revolving squirrel cages, with a properly calibrated odometer attached to the axle, so that the total amount of running which they did in their whole lives could be recorded. The results were those shown in Table 4.

TABLE 4

Relation of longevity to muscular activity in rats (Slonaker)

Total number of miles run during life

Age in months at death	Rat No. 1 Miles	No. 4 Miles	No. 2 Miles	No. 3 Miles
25	1265			
26		1391		
32			2098	
34				5447

It will be perceived that the amount of exercise taken by these rats was astonishingly large. For a rat to run 5,447 miles in the course of its life is indeed a remarkable performance. Now these 4 rats attained an average age at death of 29.5 months. But three control rats confined in stationary cages so that they could only move about to a limited degree, but otherwise under conditions, including temperature, identical with those in the revolving cages, attained an average age at death of 40.3 months. All were stated to have died of "old age." From this experiment it appears clearly that the greater the total work done, or total energy output, the shorter the duration of life, and *vice versa.* Or, put in another way, if the total activity per unit of time is increased by some means other than increasing temperature, the same results appear as if the increased activity is caused by increased temperature. It appears, in short, to be the activity *per se,* and not the temperature *per se* that is of real significance. There is other evidence, for which space lacks here, pointing in the same direction.

If we may be permitted to make a suggestion regarding the interpretation of Loeb and Northrop's results in conjunction with our own on *Drosophila,* it would be to this effect. Any given genetically pure strain of *Drosophila* is made up of individual machines, constructed to turn out before breaking down a definite limited amount of energy in the form of work, mechanical, chemical, and other. This definitely limited total energy output is predetermined by the hereditary constitution of the individual which fixes the kind of physicochemical machine that that individual is. But the *rate* per unit of time of the energy output may be influenced between wide limits by environmental circumstances in general and temperature in particular, since increased temperature increases rate of metabolic chemical changes in about the same ratio, as demonstrated by a wealth of work on temperature coefficients, as it increases other chemical changes. But if the rate of energy output per unit of time is changed, the total time taken for the total output of a predetermined amount of energy as work must change in inverse proportion to the change of rate. So we should expect just precisely the results on duration of life that Loeb and Northrop got, and so far from these results being in contradiction to ours upon

heredity they may be looked upon as a necessary consequence of them. Loeb and Northrop's final conclusion is: "The observations on the temperature coefficient for the duration of life suggest that this duration is determined by the production of a substance leading to old age and natural death or by the destruction of a substance or substances which normally prevent old age and natural death." The view which I have here suggested completely incorporates this view within itself, if we suppose that the total amount of hypothetical "substance or substances which normally prevent old age and natural death" was essentially determined by heredity.

5. Gonads and Duration of Life

There is another and quite different line of experimental work on the duration of life which may be touched upon briefly. The daily press has lately had a great deal to say about rejuvenation accomplished by means of various surgical procedures undertaken upon the primary sex organs, particularly in the male. This newspaper notoriety has especially centered about the work of Voronoff and Steinach. The only experiments which at the present time probably deserve serious consideration are those of Steinach. He has worked chiefly with white rats. His theory is that by causing through appropriate operative procedure an extensive regeneration, in a senile animal about to die, of certain glandular elements of the testis, senility and natural death will for a time be postponed because of the internal secretion poured into the blood by the regenerated "puberty glands" as he calls them. The operation which he finds to be most effective is to ligate firmly the efferent duct of the testis, through which the sperm normally pass, close up to the testis itself and before the coiled portion of the duct is reached. The result of this, according to Steinach's account, is to bring about in highly senile animals a great enlargement of all the sex organs, a return of sexual activity previously lost through old age, and a general loss of senile bodily characteristics and a resumption of the conditions of full adult vigor in those respects.

Space is lacking to go into the many details of Steinach's work, much of which is indeed chiefly of interest only to the technical biologist, and from a wholly different standpoint than the present one. I should, however, like to present one example from his experiments. As control a rat was taken in the last degree senile. He was 26 months old when the experiment began. He was obviously emaciated, had lost much of his hair, particularly on the back and hind quarters. He was weak, inactive and drowsy, as indicated by the fact that his eyes were closed, and were, one infers from Steinach, kept so much of the time.

A litter brother of this animal had the efferent ducts of the testes ligated. This animal, we are told, was at the time of the operation, in

so much worse condition of senility than his brother above described that it was not thought worth while even to photograph him. His condition was considered hopeless. To the surprise of the operator, however, he came back, slowly but surely after the operation, and after three and a half months presented a perfect picture of lusty young rathood. He was in full vigor of every sort, including sexual. He outlived his brother by 8 months, and himself lived 10 months after the operation, at which time he was, according to Steinach, practically moribund. This represents a presumptive lengthening of his expected span of life by roughly a quarter to a third. *It is to be remembered, however, that Slonaker's rats to which nothing was done lived to an average age of 40 months.*

The presumption that Steinach's experiments have really brought about a statistically significant lengthening of life is large, and the basis of ascertained fact small. After a careful examination of Steinach's brilliant contribution, one is compelled to take the view that however interesting the results may be from the standpoint of functional rejuvenation in the sexual sphere, the case is not proven that any really significant lengthening of the life span has occurred. In order to prove such a lengthening we must first of all have abundant and accurate quantitative data as to the normal variation of normal rats in respect of duration of life, and then show, having regard to the probable errors involved, that the mean duration of life after the operation has been significantly lengthened. This Steinach does not do. His paper is singularly bare of statistical data. We may well await adequate quantitative evidence before attempting any general interpretation of his results.

6. The Pituitary Gland and Duration of Life

Robertson has been engaged for a number of years past on an extensive series of experiments regarding the effect of various agents upon the growth of white mice. The experiments have been conducted with great care and attention to the proper husbandry of the animals. In consequence the results have a high degree of trustworthiness. In the course of these studies he found that the anterior lobe of the pituitary body, a small gland at the base of the brain, normally secretes into the blood stream minute amounts of an active substance which has a marked effect upon the normal rate of growth. By chemical means Robertson was able to extract this active substance from the gland in a fairly pure state and gave to it the name *tethelin.* In later experiments the effect of tethelin given by the mouth with the food was tried in a variety of ways.

In a recent paper Robertson and Ray have studied the effect of this material upon the duration of life of the white mouse with the results shown in Table 5.

TABLE 5

Effect of tethelin on duration of life in days of white mice.
(Robertson and Ray)

	MALES				FEMALES				Both sexes together
Class of animals	Average duration of life	Dev. from normal	Dev. / P. E.	Chance dev. was accidental	Average duration of life	Dev. from normal	Dev. / P. E.	Chance dev. was accidental	Chance dev. was accidental
Normal	767	----	----	------	719	----	----	-----	------
Tethelin	866	+ 99	3.00	1:22.25	800	+ 81	2.25	1:6.75	1:150.2

From this table it is apparent that the administration of tethelin with the food from birth to death prolonged life to a degree which in the case of the males may be regarded as probably significant statistically. In the case of the females where the ratio of the deviation to its probable error (Dev. / P. E.) falls to 2.25 the case is very doubtful. The procedure by which the chance of 1:150.2 that results in both sexes together were accidental, was obtained is of doubtful validity. Putting males and females together from the original table I find the following results.

TABLE 6

Duration of life of white mice, both sexes taken together
(From data of Robertson and Ray)

Age Group	No. of deaths of normals (Both Sexes)	No. of deaths of tethelin fed (Both Sexes)
200-299	3	..
300-399	2	..
400-499	2	1
500-599	9	3
600-699	7	9
700-799	15	..
800-899	10	10
900-999	10	6
1000-1099	6	9
1100-1199	..	1
	64	39

Tethelin fed: Mean age at death $= 839 \pm 20$
Normal fed: Mean " " " $= 743 \pm 17$
Difference $= 96 \pm 26$

$$\frac{\text{Difference}}{\text{P. E. Diff.}} = 3.7$$

One concludes from these figures that tethelin can be regarded as having lengthened the span of life to a degree which is just significant statistically. One would expect from the variation of random sampling alone to get as divergent results as these about 1¼ times in every 100 trials with samples of 64 and 39, respectively.

In any event it is apparent that, making out the best case possible, the differences in average duration of life produced by administration of tethelin are of a wholly different and smaller order than those which

have been shown in the earlier portion of the paper to exist between pure strains of *Drosophila* which are based upon hereditary differences.

Putting together all the results which have been reviewed in this and the preceding paper, it appears to be clearly and firmly established that inheritance is the factor of prime importance in determining the normal, natural duration of life. In comparison with this factor the influence of environmental forces (of sub-lethal immediate intensity of course) appears in general to be less marked.

ADAPTATIONS AMONG INSECTS OF FIELD AND FOREST

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IT is well known that there are more kinds or species of insects in the world than of all other animals. The number has been placed by various authorities at from one to ten million and careful estimates indicate that we have in the State of New York some 20,000 kinds or species of insects, all differing from each other by more or less striking characters and in the great majority of species, there are also recognizable variations between the eggs, the maggots, larvae or caterpillars, and the pupae or chrysalids, not to mention striking differences between the life habits of these varied forms.

Summarizing, we have among insects an immense complex exhibiting innumerable variations, some large, many minor and practically all significant. It is proposed to examine briefly some of the more striking of these differences in the hopes of reaching a better understanding of the insect problem as a whole.

It happens that some years ago a list of all the insects known to occur in the State of New Jersey was prepared and a careful analysis of this shows that nearly one-half of all the insects therein recorded are plant feeders, about one-sixth are predaceous, living mostly upon other insects, another one-sixth are scavengers and live mostly upon decaying organic matter and one-eighth are parasitic upon other animals, mostly insects.

Among plant feeders we find one or more species living at the expense of practically every growing plant. It may be that some plants, such as oak and apple trees, are particularly adapted to insect requirements and support a very large number of species. It may also be observed that practically all parts of the plant are liable to attack, including the roots, the wood or bark of the trunk, of the larger limbs, of the smaller limbs, the buds, the developing leaves and flowers in the buds, the fully developed flowers, the expanded leaves, the immature fruit and the mature fruit; and broadly speaking there are insects which confine themselves exclusively or nearly so to the parts designated. This restriction is so marked that we have a large series of small beetles known as seed weevils, because they live almost entirely in seeds of various plants. There is one entire family, the members of which

bore almost exclusively in the bark and outer sap wood of trees and because of this habit they are commonly known as bark beetles. Many of the plant feeders, it might be added, are considered injurious because of the extensive losses they cause in cultivated crops; but it should be remembered that comparatively few of the many plant feeders are numerous enough to be of economic importance.

The predaceous insects, approximately one-sixth of all the species, habitually prey upon smaller animals, mostly insects, and are indirectly beneficial because they destroy intentionally or otherwise many destructive forms. The rapid, active, brightly colored tiger beetles, many of the ground beetles, the ferocious dragon flies, the peculiar aphis lions (the young of the lazy golden-eyed fly), all come in this category together with many others.

The scavenger insects, comprising the burying beetles, many flies, etc., are nearly as numerous as the predatory forms and, like other insects, exhibit marked variations in structure and habits.

The parasites, somewhat less numerous than the two preceding groups, are in many cases indirectly beneficial since they prey upon injurious forms and incidentally hunt their prey under conditions which would frequently seem to promise immunity from attack. Here we find hyperparasitism which may involve three or even four of these pirates working in the same host and each attacking the one ahead, as it were.

Semi-aquatic and even aquatic insects are not protected by the surrounding water from parasites and also borers inhabiting deep galleries in hard wood by no means escape many enemies of this character. Even the caterpillars of the pitch moth, living and moving about readily in pitch and covered with this medium for a large proportion of their existence succumb to the attacks of these vigilant enemies. There is one entire family of small parasites which specialize upon insect eggs, some being so minute that they can develop successfully in the extremely small codling moth egg, which latter has a diameter only about one-half that of the head of an ordinary pin and is furthermore very flat and scale-like.

A general survey of insects as a whole shows all manner of variations from the minute midge approximately one-fiftieth of an inch in length to our largest moths or grass-hoppers with a wing spread of some eight inches. There are endless modifications in form from the oval body of certain beetles or even scale insects to the extremely attenuated forms such as dragon flies and walking sticks. The principal organs of the body, such as the antennae or feelers, the eyes, the legs and the wings are modified in innumerable ways and in some insects have disappeared entirely while in others they have been developed to an extraordinary degree.

We have been taught that insects have heads, wings, and legs and pass through four stages of development, namely, the egg, the larva or the caterpillar, the pupa or chrysalis and the adult; and yet modification has proceeded to such an extent that it is possible to find some insects where both structures and stages have been eliminated or concealed to such an extent that, in a broad sense, there are species or stages with and without such important accessories as heads, wings, legs, mates, eggs, larvae, pupae or chrysalids and adults.

There is also a very great variation in the time required to pass through the various transformations or what is known as the life-cycle, this ranging from approximately 7 days in certain species of plant lice or aphids to 17 years in the case of the periodical cicada, sometimes known, though improperly, as the 17 year locust.

Insects and warm weather are synonymous so to speak and yet snow fleas may be found by the millions on snow in late winter, canker worm moths fly and deposit eggs under equally adverse conditions and at this season a peculiar wingless crane fly as well as the odd Boreus may be found crawling upon the snow. The Arctic regions fairly swarm with mosquitoes which have adapted themselves to the rigors of existence in the far north and issue in clouds in the cool, Arctic spring; nevertheless it is true that most insects abound during warm weather and the midsummer months of the temperate zone and the tropical regions are remarkable for their abundance. Some thrive best under humid conditions and others have adapted themselves to the arid wastes of desert regions. These are simply suggestions regarding climatic diversities endurable by insects.

Turning from the general to special instances, aphids or plant lice illustrate in a striking manner the possibilities of relatively defenseless forms maintaining themselves under adverse conditions. These are all soft bodied insects with indifferent powers of flight and slow movement on foot; nevertheless there are something over 300 species living upon a considerable variety of plants and frequently occurring in enormous numbers. Individually, they are not particularly prolific, they are preyed upon by a considerable series of aggressive parasites and predators; but in spite of these handicaps are able to maintain themselves, because many of them produce a generation within a very short time, some 7 days, and in addition certain species at least periodically migrate to other plants. One migration is from birch to witchhazel and vice versa. This change enables the aphids to escape, for a time at least, from the frequently abundant natural enemies on the infested trees and it also provides the insects with fresh and more acceptable food, since badly infested plants soon become unsuitable for the maintenance of the insects.

The indirect effect of climate is well illustrated among aphids since a rise in temperature in warm weather in the spring is favorable to the development of a number of efficient enemies and consequently such conditions are very likely to result in a speedy control of a plant louse outbreak through natural agencies.

Certain gall making aphids exhibit very striking adaptations. Some species only curl the leaves and through such distortion obtain considerable protection from the elements and presumably also from parasites, while certain of these forms simply establish themselves upon the part of the plant selected and apparently, as a result of the withdrawal of sap due to its feeding, the adjacent plant cells grow up around the insect and eventually inclose it with protective walls, within which the mother plant louse and her young develop in security. There is such a close adaptation between plant and insect in some cases that the aphid is dependent upon finding a given species of plant and being able to establish itself upon a certain developing part, such as a leaf stem, the base of the leaf or the developing shoot.

Biological modifications among plant lice have gone farther than this and we not only find an alternation of food plants with a more or less well defined migration but also, in some species, well marked alternations of series of generations, these series being so different that before the connection was established, they were supposed to belong to entirely different species.

There is a very intimate relation between many insects and the host plant and this is especially close in the case of the oaks and the long series of gall wasps, a large and peculiar group, mostly confined to the oaks, remarkable because of the varied forms of the numerous galls they produce and noteworthy on account of the fact that a considerable series presents a peculiar phenomenon known as alternation of generations. This may be briefly described as a series of unlike alternate generations; in other words parents and children are unlike, while parents and grandchildren are alike. It appears to be a special adaptation due to the fact that one generation frequently develops upon the leaves while the other lives in galls on the twigs or even roots. The adults of one appear in warm, midsummer weather and those of the other issue under the inclement conditions of late fall or early spring.

The long series of plant feeding insects mentioned above show marked specialization in the case of some forms which actually live upon a peculiar fungus cared for and grown by themselves. This may easily be seen in the case of a number of our timber beetles, insects which make deep galleries in the dying wood of trees and utilize the moist conditions there present for the growing of a small fungus known as Ambrosia, which they carry from one tree to another. Certain species of ants, mostly tropical or sub-tropical, cultivate fungi in under-

ground chambers to which they carry portions of leaves cut from trees, using this material as a stratum upon which to grow the fungus.

It should be noted in addition that insects may be found in almost every environment. There are the salt marsh mosquitoes, for example, represented by several species, each with distinct limitations and yet so well adapted to the struggle for existence that one species, at least, may be found breeding in saline pools hundreds of miles from salt marshes. The series of fresh water mosquitoes is larger, exhibits even wider and more varied adaptations than the salt marsh forms and as an extreme case we may mention the peculiar mosquito which lives only, so far as known, in the water of pitcher plants. The silted bottom of shallow pools affords a suitable habitat for small midge larvae, one species of which may be utilized to render milk waste from creameries and cheese factories inoffensive. The maggots of another small fly are important agents in rendering sewage innocuous. The quieter portions of fresh water streams are inhabited by many caddis worms with their peculiar cases, the rapids in such streams support large patches of black fly larvae and between the adjacent stones, there may be found the delicate silken webs of fishing caddis worms. Some aquatic forms have developed to such an extent that they thrive by the millions in the very saline or alkaline lakes of the west and in at least one case the maggots of a small fly develop in pools of petroleum, a product frequently used for the destruction of insect life.

The same varied life conditions obtain among terrestrial forms. Insects are found in almost every conceivable situation, though abundance is dependent to a very great extent upon environment. One of the most remarkable cases of adaptation is found in the buffalo carpet beetle and its close allies. One species has been able to maintain itself for 17 years in an ear of very dry popcorn kept in a practically hermetically sealed fruit jar. More remarkable than this, an investigator has recently demonstrated that grubs of these beetles react to conditions so perfectly that the normal process of molting to permit increase in size and development to maturity may be reversed and in the prolonged absence of suitable nourishment these grubs may actually molt and decrease in size; and not only this but the process may be continued in either direction in individual cases through a series of molts by simply providing or withholding suitable nourishment. This behavior may well be considered an extreme illustration of adaptability so commonly found among insects.

A general knowledge of insects suggests that they have developed in such varied forms and abundance because of an inherent adaptability which has enabled them to exist under a great variety of conditions. This adaptability to environment has been sealed as it were by persistent tendencies toward structural variations, which latter incline to

become more defined whenever a group is somewhat isolated, a condition very likely to follow variations in habit. It is difficult otherwise to explain the almost endless structural modifications found among insects, because it would severely tax human ingenuity to defend them all on the ground of their bestowing a distinct advantage upon the possessor, except possibly, as suggested above, in more firmly establishing specific distinctions and the usual accompanying variations in habits. The relatively long series of similar species of such well segregated units as the cut worms and grass web worms in the Lepidoptera and the June beetles in the Coleoptera, indicate very material advantages in biological adaptations, subsequently confirmed by minor structural variations, since deviations from the normal mean a wider field for the unit as a whole and consequently a greater probability of the type persisting.

Consideration of the general problem compels the admission that insects have gained their present important position in the natural world through an adaptability unequalled in other groups. This has been accomplished by variations favorable to the invasion of unoccupied territory rather than by forcing other organisms into the background, aside from the inevitable limitations, in many cases important, which insects have imposed upon plant life. It is noteworthy that this status should be occupied by a group of comparatively weak, defenseless creatures and the fact that this has been done indicates the possibilities of adaptation. Insects have succeeded where apparently better endowed forms failed, largely because of their greater adaptability.

STUDIES OF THE OCEAN[1]

By H. S. H. THE PRINCE OF MONACO

AFTER exploring for five and twenty years all the levels of the North Atlantic Ocean, from the tropical to the polar regions, chiefly in order to enlarge our knowledge of zoological and physical oceanography, I was commencing more especially such studies as concern physiology, when the German war came and upset the lives of all workers. Eight years were then wasted in the activities of those men who devote themselves primarily to the chief interests of humanity.

Yet such is to-day the power of human thought that in the whole course of the war my oceanographical laboratories never desisted completely from this appointed task; and I was gratified with the sight of two hundred thousand boys of your army visiting the Museum at Monaco while staying on our sunny shore either to heal their wounds or to improve their strength.

When I gave more prominence in my scientific undertakings to physiology, I enjoyed the cooperation of such noted scientists as Charles Richet and Portier, or a few younger men who were thus preparing for their future. Joubin and Bouvier had previously visited with me the awful spaces of the ocean, which almost daily yielded tons of beings unknown to science—abyssal cephalopods or pelagic crustacea. Buchanan and Thoulet, those veterans of the early great labors dealing with the sea, have been for thirty years closely connected with my investigations. And the head of that pleiad, the like of which is hardly likely to be seen again in the laboratory of any ship, was Richard, director of the Oceanographical Museum at Monaco, the faithful fellow-laborer in all my voyages and consequently of all oceanographers, the best versed in our science as a whole.

Owing to Dr. Richard's ingenious ideas and to those of Commandant Bourée, there have been of late years made available large nets with extremely small meshes with which I have explored the intermediate depths of the ocean from the surface down to over 5000 meters. In some instances it has been possible, by means of a special bathometer attached to the net, to ascertain at about what level the capture has taken place.

It was already known that there exists between the great depths and the surface of the seas a fauna consisting of many species and wearing a unique aspect. A sample of that singular world is sometimes

[1] Address before The National Academy of Sciences, April 25, 1921.

THE MONACO OCEANOGRAPHICAL MUSEUM FROM THE GARDENS OF SAINT MARTIN

found floating as a corpse in the very early morning before the sea-birds have picked up these remnants of nightly struggles for life. After the improvements in our operations, unexpected facts were gradually brought to light and confirmed by other oceanographers. And in 1912 I obtained, by turning to account the bathometer above mentioned, which had been manufactured in Germany with great difficulty, the true curve of the levels the net had passed through in one operation.

Shortly after, I was able to make a net the opening and closing of which could be controlled on board the ship. This ensemble of improvements enabled us to establish, by means of operations carried out by day and by night at various depths, that there exists in those vast spaces a whole bathypelagic world undergoing vertical oscillation by which some individuals are dragged up from the lowest level at which they live to within fifty meters of the surface, the process occurring only at night. Consequently, we now find at about midnight, quite close to the surface, strange animals which we formerly, when operating in broad daylight, had to seek through most elaborate means at a depth of several thousand meters. Hence we know that those animals live in a state of perpetual vertical oscillation the period of which is twenty-four hours. We have also found that such animals as are able to undergo this enormous displacement more frequently belong to the species provided with luminous organs.

Of the broad researches to which I have applied myself for over a quarter of a century in order to throw light on the problems concerning the science of the sea, I will mention here my investigation of the currents in the North Atlantic Ocean. Those motions of the sea waters, so varied and at times so extensive, which are chiefly brought about by meteorological influences, in their turn exercise a considerable influence over life in the seas. This occurs through the distribution of the plankton, which is an entire fauna of forms extremely minute and therefore unable to direct themselves among the sea-forces.

The plankton—the miniature animal and plant forms of the sea world—is, consequently, swept about by currents over special regions of the sea and is followed by troops of stronger animals that feed upon it and are themselves fed upon by a yet mightier fauna. So it comes about that there has been established in the living sea-world, from the plankton masses to the biggest cetaceans, a broad cycle wherein we see life constantly arising out of death, amid the waters striving for their equilibrium. Currents thus exercise supreme influence over the shoals of sardine or herring, as well as a good many other fish which they supply with food under such conditions, that once upon examining the stomach of one of those fish, we could calculate the number of peridinians lying there at twenty million.

Out of the ensemble of the facts concerning the history of sea-

DREDGING WITH THE NET ON BOARD THE "PRINCESSE ALICE," THE YACHT BUILT BY THE PRINCE OF MONACO FOR THE STUDY OF OCEANIC LIFE. VOYAGE OF 1908

organisms I see more convincing grounds arise for regarding the sea as the cradle of life. Looming on the horizon of human knowledge, I descry the line of the species sprung one from another as they are distributed between surface and bottom. And while I compare that world, which has remained homogeneous through the ages, with those more distinct animals held on one plane on the earth's surface as though they had fled from the ocean, it seems to me that the whole of this terrestrial fauna because of its slower evolution tends to speedier disappearance, owing to the unstable light environment. A few groups, the pinnipedes and cetaceous mammalians, for instance, have not been able to gain even the requisite fitness and have remained half and half, with imperfect means of breathing and locomotion.

Having for a score of years observed the currents of the North Atlantic Ocean by means of extensive experiments based on organized flotation methods, I was, when the German war broke out, quite prepared for the question of what becomes of the wandering mines drifting from the mine fields which were soon placed near the coasts of both continents. I again took up my previous formulae which had enabled me to draw a chart of the great currents sweeping along or connecting Europe and America, and owing to the similarity between the drifting of mines and the method I had used during my earlier investigations it became possible for me recently to present the navigators on the North Atlantic Ocean with a very accurate chart of the course followed by those formidable engines. On this chart one can see an

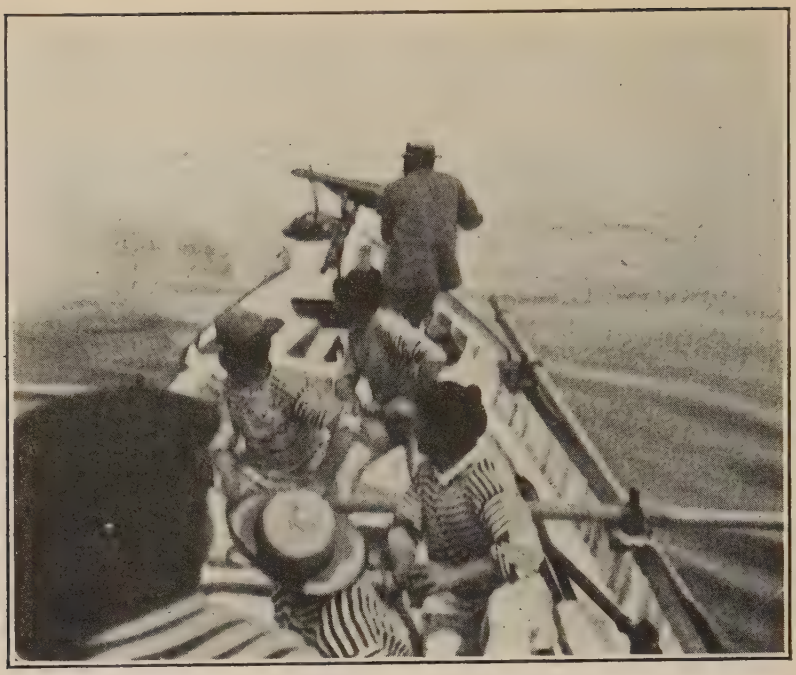
AIMING AT A WHALE (1902)

immense cycle, whose center is indicated by the Azores, described by the mines in a period of about four years, such being the space of time necessary for the completion of their voyage from the English Channel to the Canaries, the West Indies and back.

My calculations for this work are accurate with respect to the direction and the velocity of the currents, for the hydrographical and meteorological officers on both sides of the ocean observe the passing by or meeting of mines in the manner I had announced to navigators. The two sets of results mutually confirm each other after thirty-five years' interval.

I will content myself with quoting here some phenomena connected with orientation in animals in their relation to the sea.

One of my operations, carried out with a large fish-pot at a depth of about 1500 meters, brought up not only very large *Geryon* crabs, which had been caught inside, but a number of the same clinging to the outside. Thus I witnessed the perplexity the latter must have been in through want of resolution when the fish-pot was just leaving the bottom. They were merely crawlers, unable to swim; and a sudden separation from the bottom whereon the apparatus was lying prevented them from being resolute enough to drop back to their environment by simply falling down the very small height by which at first they were separated from it. They allowed themselves—for they were found to be thoroughly alive—to be lifted through a height of 1500



FIRING A LANCE HARPOON FROM A CANNON AT A WHALE IN THE ARCTIC OCEAN.
Photograph by Lieutenant Bouree

meters up to the surface in spite of the inconvenience they must have felt owing to the change in temperature and the decrease in pressure.

Another time, in the Mediterranean between Corsica and France, I met with a large whale which was apparently repairing to a predetermined goal, and accompanied it with my ship the "Princesse-Alice," keeping close to its flank. For six hours it went on the same compass-route, without departing from it more than two or three degrees, covering about 40 kilometers without a deviation although there was no visible object to guide it. Moreover, its divings and surface breathings, as measured with a chronometer, showed no marked differences, 10 minutes under water alternating with 6 to 8 breathings.

Lastly, with respect to terrestrial birds flying over the sea in their migrations, I have always found facts showing complete lack of orientation under definite circumstances. Thus they swerve from their northward or southward route when there is no more land in either of these directions. The migratory birds swept by some storm away from continental Europe at length drop down to the sea, lacking the instinct which would help them to find the lands that sometimes lie a short distance eastward.

On the other hand those birds which in their chance-guided endeavors have been so lucky as to reach the Azores never afterwards left them. Several of these islands are therefore peopled with wood-

A METEOROLOGICAL KITE FROM THE EXPLORING YACHT IN THE MEDITERRANEAN (1906)

cock and quail and wood-pigeons, which never depart; and there can be visited at São Miguel de Ponta Delgado a large collection of species captured under those circumstances.

With regard to phenomena relating to light, Messrs. Bertel and Grein have pursued very important investigations at the Monaco Oceanographical Museum concerning the penetration of the various light radiations into the depth of sea-water. Mr. Grein in particular has succeeded in securing a photographic print on highly sensitive plates exposed between 10 a. m., and 1 p. m., at a depth of 1500 meters.

The main results may be stated as follows: If we set down as 1000 the amount of light radiations reaching 1 meter down, we find that there remains at 5 meters but 3.7 of red and at 50 meters but 0.0021; at 5 meters there remains but 2.5 of orange-yellow and at 100 meters but 0.001. For green the figures are 230 at 5 meters and 0.0003 at 1000 meters; for blue they are 450 at 5 meters and 0.0001 at 1000 meters; for violet blue, 866 at 5 meters, 0.003 at 1000 meters, and 0.00001 at 1500 meters.

It was already known that the light radiations were absorbed in the above order but in what ratios they reach various depths was not known. M. Grein has moreover stated the ratios of the various percentages of radiations at any given depth: thus at a depth of 1 meter there are 96.7 per 1000 of red; 165.7 of orange yellow, green and

THE KING OF SPAIN (LEFT) AND THE PRINCE OF MONACO (RIGHT) ON BOARD THE PRINCE'S YACHT, THE "PRINCESSE ALICE," AT ST. SEBASTIAN. (JULY, 1903)

green blue; 198.9 of blue; and 207.3 of violet blue. Below 1000 meters only blue remains and below 1500 meters only violet blue.

But there is still one question of biology that offers a very great deal of interest. On my ship Dr. Charles Richet, assisted by Dr. Portier, brought to light the following facts: The tentacles of certain marine animals like *Physalia* provoke by simple contact local irritation and hypesthesia. When injected with the extracts from these tentacles the dog, the pigeon, and other animals are plunged into a state of conscious semi-narcosis more or less prolonged during which they remain absolutely insensible to pain. Richet and Portier have named this benumbing substance "hypnotoxine."

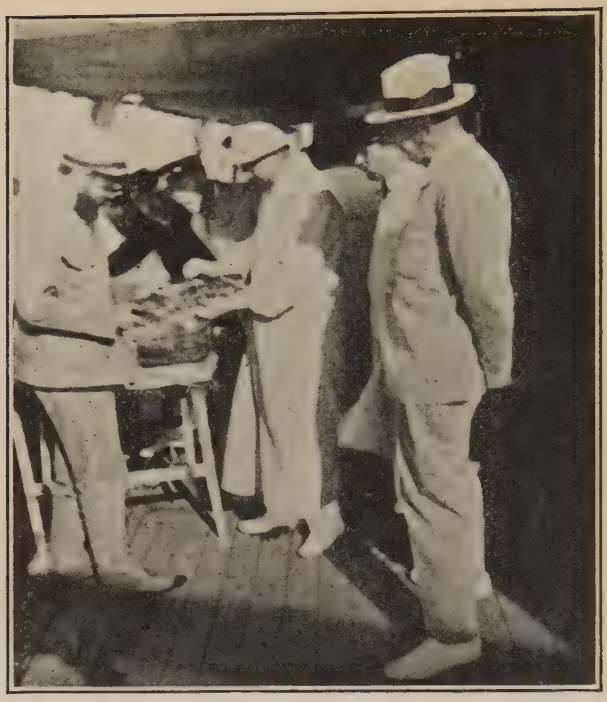
In experimenting with extracts from the tentacles of certain sea-anemones, Richet and Portier found that dogs after having received one injection became *excessively susceptible* to the action of a second dose. These dogs could be killed by a quantity representing only a fraction of the dose that would be fatal for a dog not previously treated. They gave the name "anaphylaxis" to this state of abnormal sensitiveness of a subject to the action of certain substances, which might be foreign albumens of any kind, animal or vegetable; for example, the blood-serum of an animal *of a different species*, egg-albumen, substances usually harmless like milk, the extracts of various organs, bacteria or the extracts from bacteria (bacterial proteins) etc.

THE PRINCE OF MONACO (RIGHT) AND MR. KOHN (LEFT) ON BOARD THE "PRINCESSE ALICE" ON THE VOYAGE OF 1905. Photograph by Dr. Richard, Director of the Monaco Museum

If, for example, a small amount of serum from the horse, even one one-hundredth of a cubic centimeter, is injected into a guinea-pig, the latter is rendered hypersensitive to horse serum. This hypersensitiveness goes *completely unnoticed* unless after a certain lapse of time the guinea-pig is again injected with serum from the horse; under these conditions the anaphylactic state reveals itself by a condition of "shock" with grave symptoms and sometimes even death in a few minutes.

There was at first considerable surprise and incredulity because scientists had hitherto been accustomed to regard the reaction of immunization or of diminution of sensitiveness as the appropriate response of an organism to the injection of foreign substances. It was therefore astonishing that exactly the opposite phenomenon could result. Thus the laws of immunity were completely upset.

Though but a few years have passed since the condition of anaphylaxis was studied for the first time, it has now become one of the subjects which have brought forth the most work in the domain of immunity. The amount of research carried out upon anaphylaxis is enormous, and every day its literature increases. It is a field of the highest importance not alone on account of its practical application in serum therapy but because as a mystery it enfolds within its depths the secret of many deep-seated questions relating to mankind; also



EXAMINING A CATCH OF THE BOUREE NET

because the researches already performed upon anaphylaxis give great hopes for the elucidation of these questions and for the discovery of a method of rendering the human body insusceptible.

Among the things which contribute to the harmony of our terrestrial sphere we should observe the rôle played by the marine plants as frequently intermediaries between the living and the lifeless realms of our planet. While on the one hand they furnish for many organisms both protection and nourishment, still another important function falls to their lot: they fix certain mineral substances which are more or less abundant in the bosom of the ocean and deliver them up for exploitation by human activity. Thus it would be eminently fitting to conserve and to cultivate these products of the sea which are to-day our auxiliaries in obtaining iodine, bromine, algine, chloride of sodium, and the salts of potassium, magnesium, lime, iron and manganese. Unfortunately in some places they are already the victims of waste. Finding himself in the presence of wealth, one might say, man loses completely the idea of providence. He seems then to suffer from a vertigo which drags him to the radical destruction of things for there is no gift of nature that can survive the ill-considered enterprises of human industry.

Paul Gloess has said: "It is in the marine plants that we find, and shall always find with more certainty than elsewhere, that which thus far in our carelessness we have neglected to ask of them or which

A FISHING SCENE ON BOARD THE "HIRONDELLE," THE YACHT BUILT BY THE PRINCE OF MONACO FOR OCEANIC EXPLORATION. FROM LEFT TO RIGHT ARE PRINCE ALBERT I OF MONACO; L. TINAYRE, ARTIST; DR. RICHARD, DIRECTOR OF THE MONACO MUSEUM; M. FUHRMEISTER, PRIVATE SECRETARY, AND DR. LOUET, PHYSICIAN

in our extravagance we have squandered. * * * The fertile soil of the earth is constantly becoming poorer while the nourishing fluid of the sea is growing richer and richer."

All these data are valuable for the study of the beings living at various depth-levels in the ocean.

A professor at my Oceanographical Institute, Monsieur Joubin, has lately suggested the use of seaplanes to help open-sea fishermen by guiding them towards the shoals of the fish they are seeking while the latter in their turn are pursuing large shoals of such crustacea as serve them for food. For instance, it has been found that the germon (the blue tunny in the Bay of Biscay) is plentiful in the places tenanted by certain red-colored amphipodous crustacea (*Euthemisto*) of which the germon is fond. Seaplanes would have no difficulty in signalling to fishermen those red fields which distinctly mark off certain spaces in the sea and move about as they are swept by the currents. Again, they could signal the presence of various other shoals recognizable by different signs. Thanks to this cooperation, fishermen might save time and much undue wear of their nets.

Now I shall take up a matter which I have had in hand for some time and which is one of a really serious nature. I mean fishing generally, the destructive effects of which are becoming greater and greater in the seas where more and more powerful and numerous implements such as steam trawlers are being used. The latter now graze

the very soil of continental plateaux, plucking off the sea-weeds and ruining the bottoms that are fittest for the breeding as well as the preservation of a great many species. So much so that in a few years' time the means of maintenance of hundreds of thousands of fishermen and their families on the coasts of Europe will have disappeared.

The trawlers steadily work farther and farther, deeper and deeper, in ever increasing numbers; and wherever their devastation is possible a waste is involved which certainly exceeds 50 per cent. of the edible produce they seek. For we must include in this summary valuation the young the trawl maims and kills as it passes and those that reach the ship in such condition that they are useless and in some cases untransportable. Near the Arguin bank on the west African coast a still more intensive waste occurs which is owing to purely commercial causes.

In order to check this evil, I suggest the meeting of international conferences possessing the most drastic powers to enforce the decisions that are to be arrived at. I would recommend the adoption of the reserved district principle, which has always been very efficient for the preservation of wild terrestrial species, because it rests on logic and simplicity. Besides, it is now showing its value in those parts of the sea where the war raged and fishing was held up for a few years; as soon as fishing was resumed plenty of fish has been found, some specimens being of a size unheard of for thirty years.

I have included within the domain of oceanography, for the present at least, the study of phenomena observed in the upper atmosphere floating over the oceans. That these expanses receive from the sea the principal elements of their activity seems evident when one remembers the effects of evaporation on an immense scale and of the winds which sweep continually over the surface of the waters.

Only with a great deal of difficulty have we succeded in obtaining observations on the speed and direction of the wind and the temperature and humidity of the air up to altitudes of 25,000 meters. During several years I pursued, by means of aluminum instruments weighing very little, the delicate experiments which these researches entail. In the construction of these instruments Professor Hergesell, who now accompanied me, had participated. Just as the Americans, Edy and Rotch, had already done, I at first entrusted my instruments to kites which carried them up to 4500 meters. But soon I abandoned this means and adopted a new one which, on land, furnished satisfactory results to the French investigators Hermite and Bezancon. This was an arrangement of two linked balloons unequally filled, of which the one less inflated carried the instruments. On reaching a certain height the better filled balloon would be burst by the expansion of the gas it contained, whereas the second, not sufficient alone to carry the weight of the instruments, redescended toward the surface of the sea. I was able to make such apparatus reach an altitude of 14,000 meters.

THE PRINCE OF MONACO VISITING THE GROTTO DEL CASTILLO, SPAIN, WHICH HE EXPLORED FOR PREHISTORIC HUMAN REMAINS. THE PRINCE IS SEATED ON THE RIGHT OF THE CAVE'S MOUTH, WHILE ON THE EXTREME LEFT STANDS HIS COLLABORATOR, THE ABBE BREUIL, AND NEXT TO HIM THE ARTIST OF THE EXPEDITION, LOUIS TINAYRE

The most serious difficulty presented in these operations was always that of recovering the balloon that carried the instruments after its descent to the sea, since the point of its fall was sometimes 50 to 100 miles distant from that of its ascent and in a direction quite different from what the wind at lower levels would indicate. Moreover, the whole apparatus, though followed by the ship and located repeatedly as long as it remained visible, would finally disappear without our being able subsequently to judge the effect of the wind which carried it.

On board the "Princesse-Alice II" we solved this problem by special calculations which allowed us to mark on a map, as soon as the balloon had disappeared from view, an approximate point toward which to direct the course in order to rediscover it without fail. Thanks to an ingenious idea of Professor Hergesell, this balloon left to itself remains floating with its instruments at a height of 50 meters above the water, its lifting power being recovered through a weight suspended below which has only to touch the surface.

By using much smaller balloons, of about 1-meter size, which carried no instruments but the movements of which were measured with the theodolite as long as it was possible to observe them, we succeeded, in arctic regions, in determining the velocity and direction of the wind in the upper layers of the atmosphere, even up to 25,000 meters, as before mentioned. Then our balloon was 80 kilometers from us in a straight line; that such a visibility is possible results from the limpid

THE PRINCE OF MONACO AND HIS PARTY VISIT THE GROTTO OF LA PASIEGO, NEAR PUENTE VIESGO, NOT FAR FROM SANTANDER

arctic atmosphere free from dust and water-vapor. This same limpidity permitted me one day to follow easily all the actions of 4 men whom I had sent on a mission to a snowfield situated at a distance of 40 kilometers towards the interior of Spitzbergen.

To-day, therefore, I can release in the open ocean a balloon of 2- or 3-meter size furnished with instruments and can find it mathematically after it has made a long journey in a direction of which we otherwise would have to remain totally ignorant.

I shall close my all too brief survey of the mighty domain created by the science of oceanography by speaking to this distinguished assembly of the bathymetric chart of all the seas of the globe the preparation of which I undertook at the time of the International Congress at Berlin in 1899. I realized then that this task was necessary as a basis and a program for the great work to which I have consecrated my life. To Commandant Bourée I entrusted the direction of this enterprise and to-day its imperativeness is already evident. All the hydrographic and oceanographic centers of the world have appreciated this fact and are now sending me abundant data bearing on the subject.

This chart, on a scale 1 to 1,000,000, occupies 24 sheets and measures, without its separate polar circles, 2 meters 40 cm. by 4 meters. The isobathic lines are those of 200, 500, 1000, 2000 meters, and so on.

The surfaces contained between succeeding contours are colored in blues becoming progressively deeper in shade. The oceanic regions of which the depth still remains unknown are immediately disclosed.

If we had no more rapid system for taking soundings than that which requires each time the stopping of the ship to send a lead to the bottom, many years would still be required for the completion of such a task; but the method of M. Marti, a hydrographic engineer in the French navy, will doubtless soon enable us to take lines of soundings with almost the usual speed of a ship under way.

M. Marti obtains the marking upon a very sensitive recorder of a slight explosion produced always under the same conditions. This record being repeated in like manner by the echo sent back from the submarine floor allows of a measurement of depth with greater precision than by any other procedure. The principal experiments have been carried on at the Oceanographic Museum of Monaco and it is to be hoped that M. Marti's method of sounding will be employed everywhere. When applied to slight depths it would render great services to navigation; and as for my bathymetric map, it would very soon be completed.

I have already told you that my life has been occupied in anthropological research as well as in oceanographic studies. My conjectures on the origin of life in the sea carried with them as a necessary corollary the formation of a group of beings susceptible to the laws of evolution in such a way as to be led toward the synthetic whole that has become the human form. Hence it was necessary to seek in the series of marine animals, either among the living or among the fossils which led the same life, whatever indications might shed light upon such a question. From what marine ancestors has come the stem of anthropoids from which one may ask the secret of the drama in which we are now taking part?

In the midst of these reveries came the desire to found, under the conditions of independence necessary for the development of scientific truth, a home where anthropology could grow freely in the solicitude accorded by the most trusted disciples of this science. So I created beside the Oceanographic Institute of Paris the Institute of Human Paleontology, where the professors without gathering cumbersome collections study all the materials with which excavations supply us.

I come among you the better to express my happiness and my pride in the great favor you have done me by bestowing upon me this medal which commemorates the work of oceanographers. Nothing could honor more the efforts to which I have consecrated my life that the spirit of men might no longer be left ignorant of all that concerns the science of the sea when it had already penetrated so many secrets of the earth, this infinitesimal portion of the universe.

THE PROGRESS OF SCIENCE

THE SECOND INTERNATIONAL CONGRESS OF EUGENICS

Arrangements are well advanced for the International Congress of Eugenics which will be held at the American Museum of Natural History, beginning September 22. The officers are: Honorary president, Alexander Graham Bell, Washington, D. C.; president, Henry Fairfield Osborn, Columbia University and the American Museum; honorary secretary, Mrs. C. Neville Rolfe, London; treasurer, Madison Grant, chairman of the Zoological Society, New York; secretary-general, C. C. Little, Department of Genetics, Carnegie Institution of Washington.

The congress is organized in four sections. In the first section will be presented, on the one hand, the results of research in the domain of pure genetics in animals and plants, on the other, studies in human heredity. The application to man of the laws of heredity and the physiology of reproduction as worked out on some of the lower animals will be presented. The leading address will be by Dr. Lucien Cuénot, Nancy, France.

The second section will consider factors which influence the human family and their control; the relation of fecundity of different strains and families and the question of social and legal control of such fecundity; also the differential mortality of the eugenically superior and inferior stocks and the influence upon such mortality of special factors, such as war and epidemics and endemic diseases. First in importance among the agencies for the improvement of the race is the marriage relation, with its antecendent mate selection. Such selection should be influenced by natural sentiment and by a knowledge of the significant family traits of the proposed consorts and of the method of inheritance of these traits. In this connection will be brought forward facts of improved and unimproved families and of the persistence, generation after generation, of the best as well as of the worst characteristics. The leading address will be by Dr. Herman Lundborg, Upsala, Sweden.

The third section will concern itself with the topic of human racial differences, with the sharp distinction between racial characteristics and the unnatural associations often created by political and national boundaries. In this connection will be considered the facts of the migration of races, the influence of racial characteristics on human history, the teachings of the past with bearings on the policies of the future. The results of research upon racial mixture in relation to human history will be presented. Also the topics of racial differences in diseases and psychology will be taken up. The history of race migrations and their influence on the fate of nations, especially modern immigrations, should be set forth. The leading address will be by Dr. M. V. de Lapouge, Poitiers, France.

The fourth section will discuss eugenics in relation to the state, to society and to education. It will include studies on certain practical applications of eugenic research and on the value of such findings to morals, to education, to history, and to the various social problems and movements of the day. In this section will be considered the bearing of genetical discoveries upon the question of human differences and upon the desirability of adjusting the educational program of such differences. Here will be considered the importance of

family history studies for the better understanding and treatment of various types of hospital cases and those requiring custodial care. The bearings of genetics on sociology, economics and the fate of nations may be considered in this section. The leading address will be by Major Leonard Darwin, London.

In connection with this congress a Eugenics Exhibition will be held from September 22 to October 22, in the Forestry Hall of the American Museum of Natural History. It is desired to secure the most striking exhibits available or which can be prepared for this purpose. While the exhibits must be able to withstand the test of professional scrutiny, still they should be of a nature which the man of ordinary intelligence and education, but without special scientific training, may readily comprehend and appreciate. Provision will be made for exhibiting displays of highly technical work, but the popular aspect will be given the preference.

THE EDINBURGH MEETING OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

The British Association holds its eighty-ninth annual meeting at Edinburgh, from September 7 to 14. According to an announcement in the London *Times,* the president, Sir Edward Thorpe, will address the association on aspects and problems of post-war science, pure and applied. An evening discourse will be given by Professor C. E. Inglis on a comparison of the Forth and Quebec Bridges, and there will be an opportunity to visit the former. Another discourse will be given on Edinburgh and oceanography by Professor W. A. Herdman, who, it will be remembered, as president of the association at Cardiff last year, pressed for a new exploration of the oceans like that of the *Challenger,* nearly 50 years ago.

Some presidents of sections will introduce discussions on their addresses. Hitherto all addresses have been formally read, and never discussed, but in the present program the following addresses are announced to initiate debates: Sir W. Morley Fletcher, on the boundaries of physiology; Professor Lloyd Morgan, on consciousness and the unconscious, opening the newly established section of psychology; Dr. D. H. Scott, on the present position of the theory of descent in relation to the early history of plants; Sir Henry Hadow, on the place of music in a liberal education; and Mr. C. S. Orwin, on the study of agricultural economics. Other addresses will be given on problems of physics by Professor O. W. Richardson, on the laboratory of the living organism by Dr. M. O. Forster, by Dr. J. S. Flett on experimental geology, by Professor E. S. Goodrich on some problems in evolution, by Dr. D. G. Hogarth on the application of geography, by Mr. W. L. Hichens on principles by which wages are determined, and by Professor A. H. Gibson on water power.

This year the council called all sectional committees to meet together to consider common action, and out of many suggestions then received several topics of first-rate importance were selected to be debated by appropriate groups of sections, at joint meetings which will form the principal items of the sectional programs. These topics include the structure of molecules, the age of the earth, biochemistry, the proposed Mid-Scotland canal, the origin of the Scottish people, vocational training and tests and the relation of genetics to agriculture.

Among the other promised features there is a popular exposition of Einstein's theory of relativity by Professor A. S. Eddington; and the usual public lectures will be given to the

Photographed by Underwood and Underwood.

DR. LIVINGSTON FARRAND

Elected president of Cornell University to succeed Dr. Jacob Gould Schurman. President Farrand has been adjunct professor of psychology and professor of anthropology in Columbia University, president of the University of Colorado and chairman of the Central Committee of the American Red Cross.

citizens of Edinburgh. The speakers will include Sir Oliver Lodge on speech through the ether, Professor A. Dendy on the stream of life, and Professor H. J. Fleure on countries as personalities, and a special lecture will be arranged on market day in Edinburgh for the agricultural community by Dr. E. J. Russell on science and crop production.

The association, having failed to regain its former concession of reduced railway fares for members, proposes that they shall be offered facilities for traveling by motor coach to Edinburgh from most of the university and many other principal towns in England, at fares substantially less than those of the railways. Full particulars of membership may be had from the office of the association at Burlington House, or from the local secretary at the University of Edinburgh.

MEETINGS OF BRITISH AND AMERICAN CHEMISTS

Joint meetings will be held this autumn by chemists of Great Britain, Canada and the United States. Members of the Society of Chemical Industry of Great Britain will join with the Canadian branch of their organization in sessions in Montreal late in August. The scientific and business sessions will center at McGill University, where there will be a special convocation. The Canadian and British chemists will inspect numerous plants and will proceed to Ottawa and Toronto, where they will be entertained by the local sections. On September 5, they will reach Niagara Falls, where they will view the vast establishments which modern physics and chemistry have created.

The members will then cross the border, being met by a committee of the American section of their society and conducted through the industrial plants on this side of the Falls. Dinner will be served at Buffalo, and on their arrival at Syracuse, they will have luncheon with the Solvay Process Company. The chemists will then go to Albany and New York City, where they will be welcomed by the American Section of the Society of Chemical Industry. Elaborate arrangements for the reception of the chemists will be carried out, through the co-ordinating committee, of which Dr. B. C. Hesse is chairman and Dr. Allen Rogers is secretary. The festivities, meetings and entertainments which will follow are designed to bring into closer bonds all chemists of Anglo-Saxon stock.

The fall meeting of the American Chemical Society, with its 15,500 members, is to be held in New York City from September 6 to 10, inclusive. The first contact will be at a lawn party, to be given on the afternoon of September 7 to foreign guests and to scientific societies at Columbia University. Other societies asked to participate in the welcoming of the visitors from abroad are: The American Electrochemical Society; the American Institute of Chemical Engineers; the American Section of the Société de Chimie Industrielle; and the Manufacturing Chemists' Association of the United States. The foreign guests have also been invited to the smoker and entertainment of the American Chemical Society, which will be held on the evening of Wednesday, September 7.

Scientific sessions of the American Chemical Society, in which many matters concerning chemical research and applied chemistry will be discussed, are to be held at Columbia University. To these meetings the British and Canadian guests have been bidden. They will also be present at the banquet of the American Chemical Society on the evening of September 9 at the Waldorf-Astoria.

The fortnight beginning September 12 will be dedicated to American

Photographed by Harris and Ewing.

EDWARD BENNETT ROSA

chemistry in all its phases, for it marks the holding of the National Exposition of Chemical Industries, which is to be held in the Coast Artillery Armory in the Bronx. There will be brought together under one roof a demonstration of what has been accomplished in this country since the European War in adapting the resources of the United States to national needs.

EDWARD BENNETT ROSA

The death of Dr. Edward Bennett Rosa, chief physicist of the Bureau of Standards, Washington, D. C., is a serious loss to science and to the government service. Born in Rogersville, N. Y., in 1861, he was a graduate of Wesleyan University in the class of 1886, receiving the degree of doctor of philosophy from the Johns Hopkins University in 1891. For a short time he was instructor at the University of Wisconsin, leaving there to become professor of physics at Wesleyan University. He became the chief physicist at the Bureau of Standards in 1901.

He did notable work in science and electrical engineering. At Wesleyan University he developed the physical side of the respiration calorimeter with Professor W. O. Atwater. This apparatus was of great value in the pioneer investigations on the value of foods and the study of nutrition problems. He took a leading part in the researches to establish the fundamental electrical units after going to the Bureau of Standards and served as secretary of the International Committee on Electrical Units and Standards. He has developed the electrical work of the Bureau of Standards from small beginnings into an organization covering the scientific and engineering aspects of a great national laboratory.

When Dr. Rosa began his work in the Electrical Division it was his ambition to determine a number of the fundamental electrical constants. In conjunction with Dr. Dorsey he immediately undertook the determination of the ratio of the electromagnetic and electrostatic units. About 1907 they started their work on the determination of the ampère. This was followed by work on the silver voltameter and apparatus for determining the absolute value of the ohm.

During his early years at the bureau, Dr. Rosa published a large number of papers on the computing of inductance, and later, with Dr. Grover, he collected together practically all the known formulae for computing inductance. In 1910, there was instituted under Dr. Rosa's direction an exhaustive investigation into the subject of electrolytic corrosion of underground gas and water pipes, and lead cable sheaths due to stray currents from electric railways.

During the war, Dr. Rosa directed the development of a number of scientific instruments which were of inestimable value to the American Forces in France. Among these might be mentioned a sound-ranging device for locating big guns; the geophone for the detection of mining operations, the development of aircraft radio-apparatus, and the improvement of radio.

In addition to his diversified work in the field of electrical research, Dr. Rosa was keenly interested in the prevention of industrial accidents and in the promulgation of safety standards for use by state, municipal and insurance organizations. He conceived the idea of a National Electrical Safety Code several years ago, and the present code is largely the result of his efforts. Similarly the bureau has undertaken a number of other national safety codes, the Safety Code Section working under his direction.

His broad vision showed him the need of a central clearing house for

engineering standards. For years he worked whole-heartedly to bring about the formation of such an organization. It was due in no small measure to his efforts that the American Engineering Standards Committee is now functioning.

The broader aspects of the scientific and engineering work of the Federal Government were clearly presented in a series of papers by Dr. Rosa. His analysis of government expenditures, printed in this journal, was largely quoted by leading periodicals as well as in both Houses of Congress.

SCIENTIFIC ITEMS

We record with regret the death of Dr. Francis Bacon Crocker, the electrical engineer, formerly professor at Columbia University; of Dr. Marshman Edward Wadsworth, dean emeritus of the School of Mines of the University of Pittsburgh, and of Dr. Gabriel Lippman, professor of physics in the University of Paris.

Dr. Frank Pierrepont Graves, dean of the school of education of the University of Pennsylvania, has been appointed commissioner of education of the state of New York and president of the University of the State of New York.

The Adamson lecture was delivered at the University of Manchester on June 9 by Professor Einstein, who had been invited by the council in accordance with a senate recommendation passed on February 3. At the opening of the proceedings the honorary degree of D.Sc. was conferred on him. Professor Einstein lectured on June 13 at King's College, London, on "The development and present position of the theory of relativity." After the public lecture Professor Einstein was the guest of the principal of King's College at a dinner given in the college.

The Louisiana State University will receive $7,500,000 for new buildings and equipment as a result of the action of the Constitutional Convention which has just adjourned, this sum having been set apart for the purpose from funds accruing from the newly established severance tax on oil and other natural resources. Plans are now being made for the erection of the new buildings on a tract of two thousand acres near Baton Rouge, Olmstead Brothers, of Brookline, Mass., having been secured as landscape architects. The new constitution, which has just gone into effect, also provides for a half-mill tax, which it is estimated will yield an annual income of approximately a million dollars for the maintenance of the university.

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1921

THE BIOLOGY OF DEATH—VII. NATURAL DEATH, PUBLIC HEALTH, AND THE POPULATION PROBLEM[1]

By Professor RAYMOND PEARL

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1. Summary of Results

IN this series of papers I have attempted to review some of the important biological and statistical contributions which have been made to the knowledge of natural death and the duration of life, and to synthesize these scattered results into a coherent unified whole. In the present paper I shall endeavor to summarize in the briefest way the scattered facts which have been passed in review in the series, and to follow a presentation of the general results to which they lead with some discussion of what we may reasonably regard the future as having in store for us, so far as may be judged from our present knowledge of the trend of events.

What are the general results of our review of the general biology of death? In the first place, one perceives that natural death is a relatively new thing which appeared first in evolution when differentiation of cells for particular functions came into existence. Unicellular animals are and always have been immortal. The cells of higher organisms, set apart for reproduction in the course of differentiation during evolution, are immortal. The only requisite conditions to make their potential immortality actual are physico-chemical in nature and are now fairly well understood, particularly as a result of the investigations of Loeb upon artificial parthenogenesis and related phenomena. The essential and important somatic cells of the body, however much differentiated, are also potentially immortal, but the conditions necessary for the actual realization of the potential immortality are, in the nature of the case, as has been shown by the brilliant researches of Leo Loeb, Harrison and Carrel on tissue culture,

[1] Paper from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, Johns Hopkins University, No. 34.

such as can not be realized so long as these cells are actually in and a part of the higher metazoan body. The reason why this is so, and why in consequence death results in the Metazoa, is that in such organisms the specialization of structure and function necessarily makes the several parts of the body mutually dependent for their life upon each other. If one organ or group breaks down, the balance of the whole is upset and death follows. But the individual cells themselves could go on living indefinitely if they were freed, as they are in cultures, of the necessity of depending upon the proper functioning of other cells for their food, oxygen, etc.

So then we see emerging, as our first general result, the fact that natural death is not a necessary or inevitable consequence of life. It is not an attribute of the cell. It is a by-product of progressive evolution—the price we pay for differentiation and specialization of structure and function.

The first result leads logically to the attachment, in any particular organism such as man, of great importance to the quantitative analysis of the manner in which different parts of the body break down and lead to death. Such an analysis, carefully worked through, demonstrates that this breaking down is not a haphazard process, but a highly orderly one resting upon a fundamental biological basis. The progress of the basic tissue elements of the body along the evolutionary pathway is the factor which determines the time when the organ systems in which they are chiefly involved shall break down. Those organ systems that have evolved farthest away from original primitive conditions are the soundest and most resistant, and wear the longest under the strain of functioning. So then, the second large result is that it is the way potentially immortal cells are put together in mutually dependent organ systems that immediately determines the time relations of the life span.

But it was possible to penetrate more deeply into the problem than this by finding that the duration of life is an inherited character of an individual, passed on from parent to offspring, just as is eye color or hair color, though not with the same degree of precision. This has been proved in a variety of ways, first directly for man (Pearson) and for a lower animal, *Drosophila*, (Hyde, Pearl) by measuring the degree of hereditary transmission of duration of life, and indirectly by showing that the death rate was selective (Pearson, Snow, Bell, Ploetz) and had been since nearly the beginning of recorded history, at least. It is heredity which determines the way the organism is put together—the organization of the parts. And it is when parts break down and the organization is upset that death comes. So the third large result is that heredity is the primary and fundamental determiner of the length of the span of life.

Finally, it is possible to say *probably*, though not as yet definitely because the necessary mass of experimental evidence is still lacking, but will I believe be shortly provided, that environmental circumstances play their part in determining the duration of life largely, if not in principle entirely, by influencing the *rate* at which the vital patrimony is spent. If we live rapidly, like Loeb and Northrop's *Drosophila* at the high temperatures, our lives may be gayer, but they will not be so long. The fact appears to be, though reservation of final judgment is necessary till more returns are in, that heredity determines the amount of capital placed in the vital bank upon which we draw to continue life, and which when all used up spells death, while environment, using the term in the broadest sense to include habits of life as well as physical surroundings, determines the rate at which drafts are presented and cashed. The case seems in principle like what obtains in respect of the duration of life of a man-constructed machine. It is self-evident that if of two automobiles of the same make leaving the factory together new at the same time, one is run at the rate of 1,000 miles per year and the other at the rate of 10,000 miles per year, the useful life of the former is bound to be much longer in time than that of the latter, accidents being excluded in both cases. Again, a very high priced car, well-built of the finest materials, may have a shorter duration of life than the shoddiest tin bone-shaker, provided the annual mileage output of the former is many times that of the latter.

The first three of these conclusions I believe to be as firmly grounded as any of the generalizations of science. The last rests at present upon a much less secure footing. Because it does, it offers an extremely promising field for both statistical and experimental research. We need a wide variety of investigations, like those of Loeb and Northrop and of Slonaker, on the experimental side. On the statistical side, well-conceived and careful studies, by the most refined of modern methods, upon occupational mortality seem likely to yield large returns.

2. Public Health Activities

Fortunately, it is possible to get some light on the environmental side from existing statistical data by considering in a broad general way the results of public-health activities, so-called. Any public-health work, of course, deals and can deal in the present state of public sentiment and enlightenment only with environmental matters. Attempts at social control of the germ-plasm—the innate inherited constitutional make-up—of a people, by eugenic *legislation*, have not been conspicuously successful. And there is a good deal of doubt, having regard to all the factors necessarily involved, whether they have always

been even well-conceived. As an animal breeder of some years' experience, I have no doubt whatever that almost any breeder of average intelligence, if given omnipotent control over the activities and destinies of human beings, could in a few generations breed a race of men on the average considerably superior—*by our present standards*—to any race of men now existing in respect of many of his qualities or attributes. But, as a practical person, I am equally sure that nothing of the sort is going to be done by legislative action or any similar delegation of powers. Before any sensible person or society is going to entrust the control of its germ-plasm to science, there will be demanded that science know a great deal more than it now does about the vagaries of germ-plasms and how to control them. Another essential difficulty is one of standards. Suppose it to be granted that our knowledge of genetics was sufficiently ample and profound to make it possible to make a racial germ plasm exactly whatever one pleased; what individual or group of individuals could possibly be trusted to decide what it should be? Doubtless many persons of uplifting tendencies would promptly come forward prepared to undertake such a responsibility. But what of history? If it teaches us anything, it is that social, moral and political standards change, and change radically, with the passing of time. What a group of omnipotent thirteenth century geneticists—all well-meaning, sincere, and, for their time, enlightened individuals—would have thought to be an ideal race of human beings would be very far from what we should so regard to-day. One can not but feel that man's instinctive wariness about experimental interferences with his germ plasm is well-founded.

But because of the altogether more impersonal nature of the case, most men individually and society in general are perfectly willing to let anybody do anything they like in the direction of modifying the environment, or trying to, quite regardless of whether science is able to give any slightest inkling on the basis of ascertained facts as to whether the outcome will be good, bad or indifferent. Hence many kinds of weird activities and propaganda flourish like the proverbial bay tree, and with a singularly unanimous and outspoken manifestation of that unenlightened self-indifference, which is so charming a characteristic of the highest descendants of the anthropoids collectively, we go on paying out large sums of money to the end that they may continue to flourish.

Of all activities looking towards the direct modification of the environment to the benefit of mankind, that group comprised under the terms sanitation, hygiene and public health have by all odds the best case when measured in terms of accomplishment. Man's expectation of life has increased as he has come down through the centuries (cf. Pearson and Macdonell.) A very large part of this improvement

must surely be credited to his improved understanding of how to cope with an always more or less inimical environment and assuage its asperities to his greater comfort and well-being. To fail to give this credit would be manifestly absurd.

But it would be equally absurd to attempt to maintain that all decline in the death-rate which has occurred has been due to the efforts of health officials, whether conscious or unconscious. The open-minded student of the natural history of disease knows perfectly well that a large part of the improvement in the rate of mortality can not possibly have been due to any such efforts. To illustrate the point, I have prepared a series of illustrations dealing with conditions in the Registra-

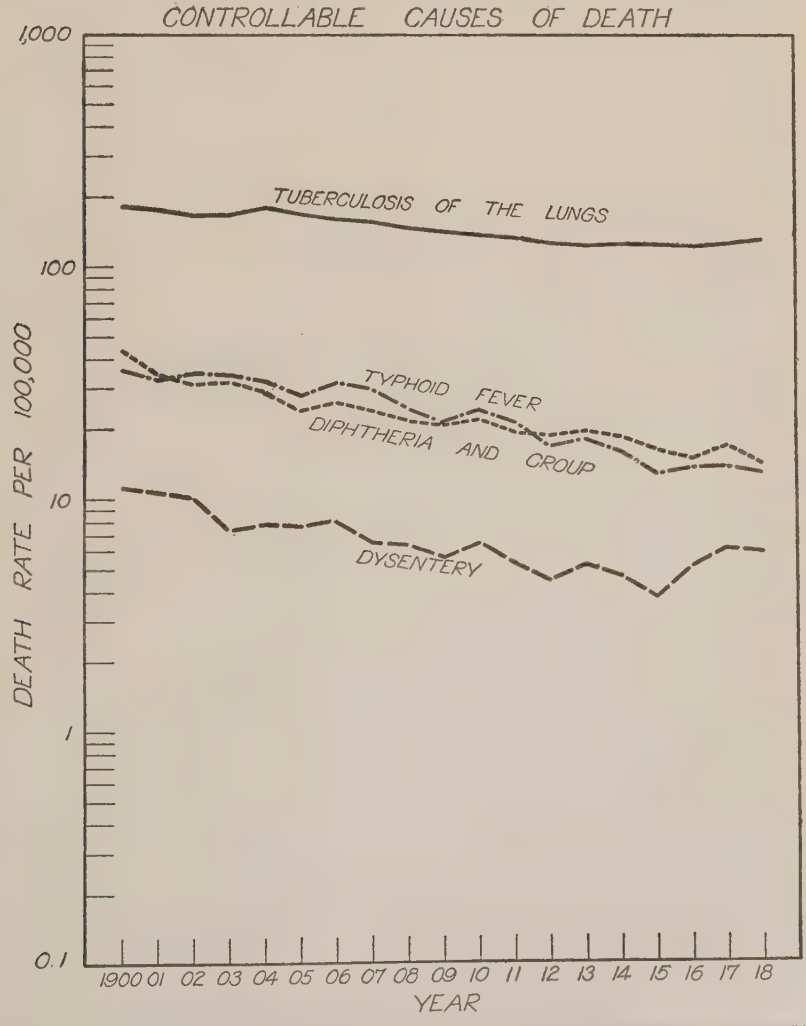

FIG. 1. TREND OF DEATH RATES FOR FOUR CAUSES OF DEATH AGAINST WHICH PUBLIC HEALTH ACTIVITIES HAVE BEEN PARTICULARLY DIRECTED

tion Area of the United States in the immediate past. All these diagrams (Figures 1, 2, and 3) give death rates per 100,000 from various causes of death in the period of 1900-1918, inclusive, both sexes for simplicity being taken together. The lines are all plotted on a logarithmic scale. The result of this method of plotting is that the slope trend of each line is directly comparable with that of any other, no matter what the absolute magnitude of the rates concerned. It is these slopes, measuring improvement in mortality, to which I would especially direct attention.

In Figure 1 are given the trends of the death rates for four diseases against which public health and sanitary activities have been particularly and vigorously directed, with, as we are accustomed to say, most gratifying results. The diseases are:

1. Tuberculosis of the lungs.
2. Typhoid fever.
3. Diphtheria and croup.
4. Dysentery.

We note at once that the death rates from these diseases have all steadily declined in the 19 years under review. But the rate of drop has been slightly unequal. Remembering that the slopes are comparable, wherever the lines may lie, and that an equal slope means a *relatively* equally effective diminution of the mortality of the disease, we note that the death-rate from tuberculosis of the lungs has decreased slightly less than any of the other three. Yet it may fairly be said that so strenuous a warfare, or one engaging in its ranks so many earnest and active workers, has probably never in the history of the world been waged against any disease as that which has been fought in the United States against tuberculosis in the period covered. The rates of decline of the other three diseases are all practically identical.

Figure 2 shows entirely similar trends for four other causes of death—namely:

1. Bronchitis (Acute and Chronic).
2. Paralysis without specified cause.
3. Purulent infection and septicemia.
4. Softening of the brain.

Now it will be granted at once, I think, that public health and sanitation can have had, at the utmost, extremely little if anything to do with the trend of mortality from these four causes of death. For the most part they certainly represent pathological entities far beyond the present reach of the health officer. Yet the outstanding fact is that their rates of mortality have declined and are declining just as did those in the controllable group shown in Figure 1. It is of no moment to say that the four causes of death in the second group are *absolutely* of less importance than some of those in the first group, because what we are here discussing is not relative force of mortality from different causes, but rather the *trend* of mortality from particular causes. The

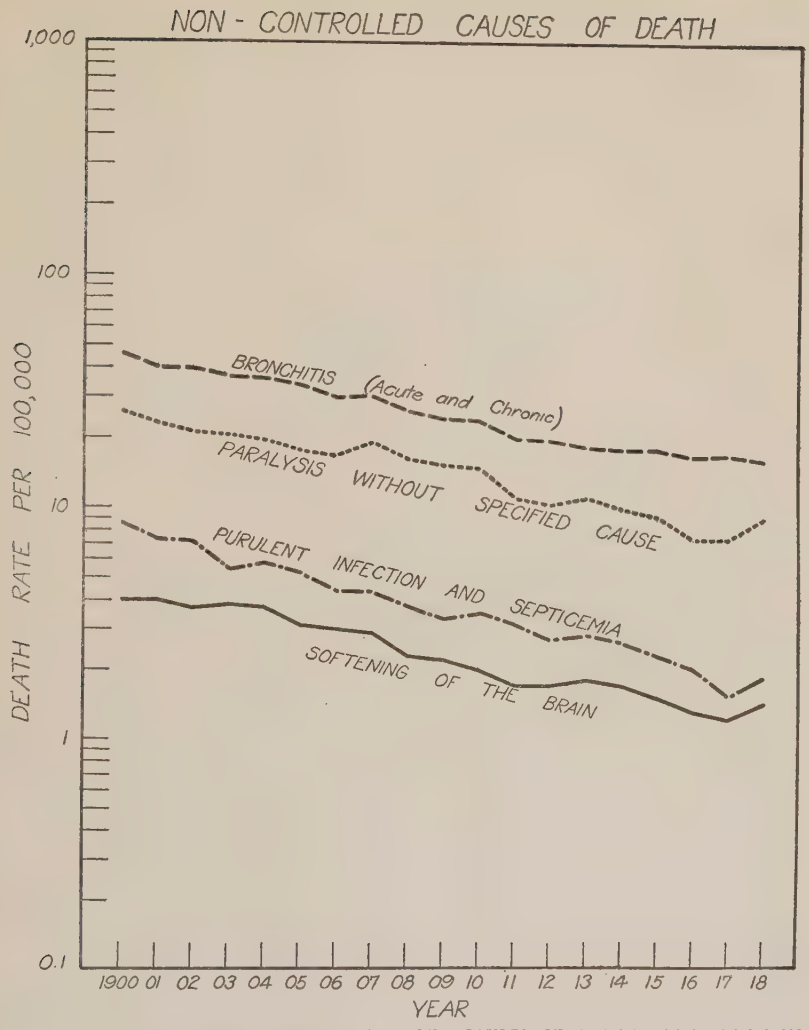

FIG. 2. TREND OF DEATH RATES FROM FOUR CAUSES OF DEATH UPON WHICH NO DIRECT ATTEMPT AT CONTROL HAS BEEN MADE

rate of decline is just as significant, whatever the absolute point from which the curve starts.

It is difficult to carry in the mind an exact impression of the slope of a line, so, in order that a comparison may be made, I have plotted in Figure 3, first, the total rate of mortality from the four controllable causes of death taken together and, second, the total rate of mortality from the four uncontrolled causes taken together. The result is interesting. The two lines were actually nearer together in 1900 than they were in 1918. They have diverged because the mortality from the uncontrolled four has actually decreased faster in the 19 years than has that from the four against which we have been actively fighting.

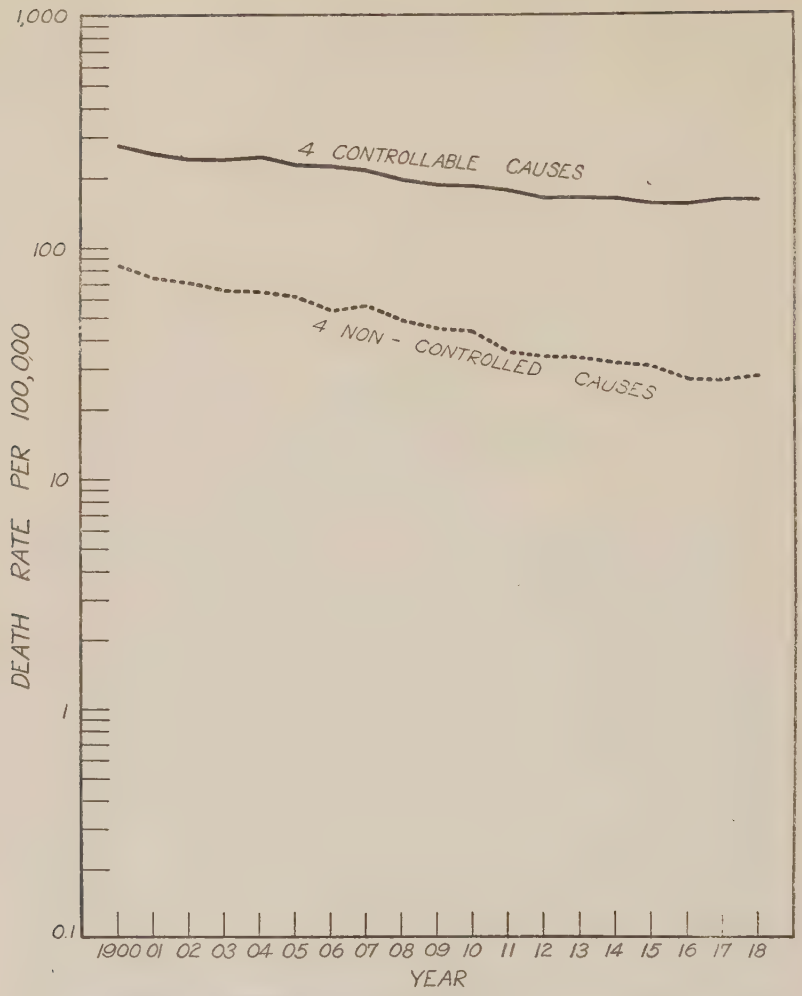

FIG. 3. TREND OF COMBINED DEATH RATE FROM THE FOUR CAUSES SHOWN IN FIGURE 1 AS COMPARED WITH THE FOUR CAUSES SHOWN IN FIGURE 2

The divergence is not great, however. Perhaps we are only justified in saying that the mortality in each of the two groups has notably declined, and at not far from identical rates.

Now the four diseases in this group I chose quite at random from among the causes of death whose rates I knew to be declining, to use as an illustration solely. I could easily pick out eight other causes of death which would illustrate the same point. I do not wish too much stress to be laid upon these examples. If they may serve merely to drive sharply home into the mind that it is only the tyro or the reckless propagandist long ago a stranger to truth who will venture to assert that a declining death-rate in and of itself marks the successful result of human effort, I shall be abundantly satisfied.

There is much in our public health work that is worthy of the highest praise. When based upon a sound foundation of ascertained fact it may, and does, proceed with a step as firm and inexorable as that of Fate itself, to the wiping out of preventable mortality. Some of the work, one regrets to say, has no such foundation, but is built upon the exceedingly shifty sands of ignorance. Having jumped without the slightest real evidence to an unsupported conclusion, the public health propagandist puts into active practice and at great public expense measures which totally lack any scientific validity. I am in great sympathy with the words of the distinguished English pathologist, William Bulloch, who said, in discussing tuberculosis, that he wished "to enter a protest against the wild statements now being made in the lay and medical press, that the whole problem of phthisis was one of infection. Medical history showed that in tuberculosis, as also in the case of other diseases, the most extreme views were taken, not by those who had contributed the actual advancement in knowledge, but by those whose business it was to apply those advancements for the needs of the public. There were a large number of well-ascertained facts which were not entirely explicable on the doctrine that disposition was not an important factor in the genesis of the disease, and that before rigorous measures were applied on a wide scale the actual facts should be ascertained. He did not agree that public health authorities must always 'do something.' This 'doing something' should be put a stop to until there was a reasonable supposition that it was going to achieve its end. He did not wish it to be understood that the tubercle bacillus was not a potent factor. What he did refuse to believe was that it was the only factor. He considered that the disposition, the power of the individual to resist the aggressive inroads of the bacillus, was greater than many people held at the present day."

While this statement of Bulloch's turns upon a controverted issue in the etiology of clinical tuberculosis, namely, as to the relative influence of heredity and environment, the same principle applies to some other phases of public-health work. We shall save a good deal of money and human energy, if we first take the trouble to prove that what we are undertaking to do is in any degree likely to achieve any useful end.

3. The Population Problem

Turning to another phase of the problem, it is apparent that if, as a result of sanitary and hygienic activities and natural evolution, the average duration of human life is greater now than it used to be and is getting greater all the time, then clearly there must be more people on the earth at any time out of a given number born than was formerly the case. It is furthermore plain that if nothing happens to the birth-

rate there must eventually be as many persons living upon the habitable parts of the globe as can possibly be supported with food and the other necessities of life. Malthus, whom every one discusses but few take the trouble to read, pointed out many years ago that the problem of population transcends, in its direct importance to the welfare of human beings and forms of social organization, all other problems. Lately we have had a demonstration on a ghastly gigantic scale of the truth of Malthus' contention. For in last analysis it can not be doubted that the underlying cause of the great war through which we have just passed was the ever-growing pressure of population upon subsistence.

Any system or form of activity which tends by however slight an amount to keep more people alive at a given instant of time than would otherwise remain alive adds to the difficulty of the problem of population. We have just seen that this is precisely what our public-health activities aim to do, and in which they succeed in a not inconsiderable degree. But someone will say at once that while it is true that the death-rate is falling more or less generally, still the birth-rate is falling concomitantly, so we need not worry about the population problem. It is evident that if we regard the population problem in terms of world-area, rather than that of any particular country, its degree of immediacy depends upon the ratio of births to deaths in any given time unit. If we examine, as I have recently done, these death-birth ratios for different countries, we find that they give us little hope of any solution of the problem of population by virtue of a supposed general positive correlation between birth rates and death rates.

The relation of birth-rate and death-rate changes to population changes is a simple one and may be put this way. If, neglecting migration as we are justified in doing in the war period and in considering the world problem, in a given time unit the percentage

$$\frac{100 \text{ Deaths}}{\text{Births}}$$

has a value less than 100, it means that the births exceed the deaths and that the population is increasing within the specified time unit. If, on the other hand, the percentage is greater than 100, it means that the deaths are more frequent than the births and that the population is decreasing, again within the specified time unit. The ratio of deaths to births may be conveniently designated as the vital index of a population.

From the raw data of births and deaths, I have calculated the percentage which the deaths were of the births for (a) the 77 non-invaded departments of France; (b) Prussia; (c) Bavaria; and (d) England and Wales, from 1913 to 1920 by years. The results are shown in Table 1.

TABLE 1

Percentage of Deaths to Births

Year	77 non-invaded departments of France	Prussia	Bavaria	England and Wales
1913	97 per cent	.....	58 per cent.	57 per cent.
1914	110 " "	66 per cent.	74 " "	59 " "
1915	169 " "	101 " "	98 " "	69 " "
1916	193 " "	117 " "	131 " "	65 " "
1917	179 " "	140 " "	127 " "	75 " "
1918	198 " "	132* " "	146 " "	92 " "
1919	154 " "	.....	.....	73 " "
1920	.....	.....	.....	42* " "

* First three-fourths of year only.

The points to be especially noted in Table 1 are:

1. In all the countries here dealt with the death-birth ratio in general rose throughout the war period. This means that the proportion of deaths to births increased so long as the war continued.

2. But in England it never rose to the 100 per cent. mark. In other words, in spite of all the dreadful effects of war, England's net population went on increasing throughout the war.

3. Immediately after the war was over, the death-birth ratio began to drop rapidly in all countries. In England in 1919 it had dropped back from the high figure of 92 per cent. in 1918 to 73 per cent. In France it dropped from the high figure of 198 in 1918 to 154 in 1919, a lower figure than France had shown since 1914. In all the countries the same change is occurring at a rapid pace.

Perhaps the most striking possible illustration of this is the history of the death-birth ratio of the city of Vienna, shown in Figure 4, with data from the United States and England and Wales for comparison. Probably no single large city in the world was so hard hit by the war as Vienna. Yet observe what has happened to its death-birth ratio. Note how sharp is the decline in 1919 after the peak in 1918. In other words, we see how promptly the growth of population tends to regulate itself back towards the normal after even so disturbing an upset as a great war.

In the United States, the death-birth ratio was not affected at all by the war, though it was markedly so by the influenza epidemic. The facts are shown in Figure 4 for the only years for which data are available. The area covered is the United States birth registration area. We see that with the very low death-birth ratio of 56 in 1915, there was no significant change till the influenza year 1918, when the ratio rose to 73 per cent. But in 1919, it promptly dropped back to the normal value of 57.98, almost identical with the 1917 figure of 57.34.

In England and Wales, the provisional figure indicates that 1920

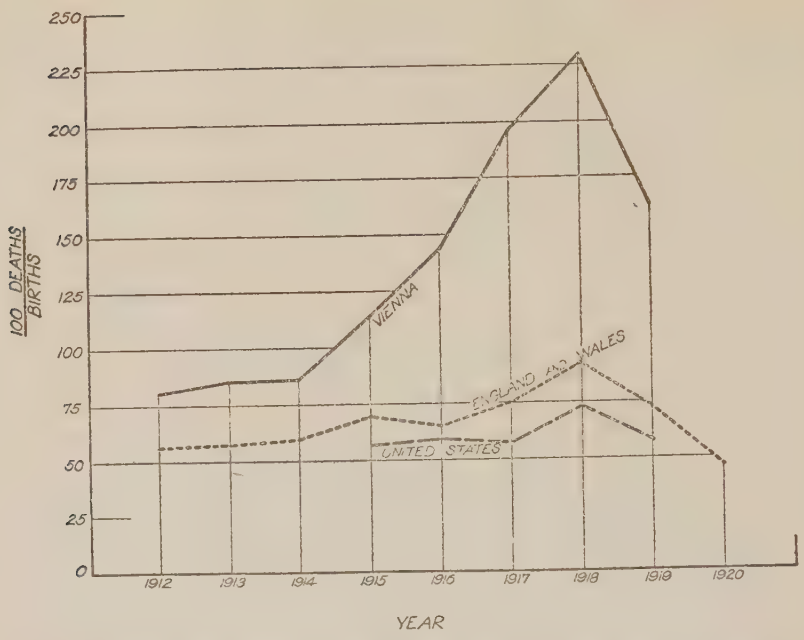

FIG. 4. SHOWING THE CHANGE IN PERCENTAGE WHICH DEATHS WERE OF BIRTHS IN EACH OF THE YEARS 1912 TO 1919 FOR VIENNA (———); 1915 TO 1919 FOR THE UNITED STATES (— — —); AND 1912 TO 1920 FOR ENGLAND AND WALES (------)

will show a lower value for the vital index than that country has had for many years.

So we see that neither the most destructive war the modern world has ever known nor the most destructive epidemic since the Middle Ages serves more than to cause a momentary hesitation in the steady onward march of population growth.

The first thing obviously needed in any scientific approach to the problem of population is a proper mathematical determination and expression of the law of population growth. It has been seen that the most devastating calamities make but a momentary flicker in the steady progress of the curve. Furthermore, population growth is plainly a biological matter. It depends upon, in last analysis, only the basic biological phenomena of fertility and mortality. To the problem of an adequate mathematical expression of the normal growth of populations, my colleague, Dr. Lowell J. Reed, and I have addressed ourselves for some time past. The known data upon which we have to operate are the population counts given by successive censuses. Various attempts have been made in the past to get a mathematical representation of these in order to predict successfully future populations, and to get estimates of the population in inter-censal years. The most noteworthy attempt of this sort is Pritchett's fitting of a parabola of the third order to the United States population from 1790 to 1880 in-

clusive. This gave a fairly good result over the period, but was obviously purely empirical, expressed no real biological law of change, and in fact failed badly in prediction after 1890.

We have approached the problem from an *a priori* basis, set up a hypothesis as to the biological factors involved, and tested the resulting equation against the facts for a variety of countries. The hypothesis was built up around the following considerations:

1. In any given land area of fixed limits, as by political or natural boundaries, there must necessarily be an upper limit to the number of persons that can be supported on the area. To take an extreme case, it is obvious that not so many as 25,000 persons could possibly stand upon an acre of ground, let alone live on it. So similarly there must be for any area an upper limiting number of persons who can possibly live upon it. In mathematical terms this means that the population curve must have an upper limiting asymptote.

2. At some time in the more or less remote past the population of human beings upon any given land area must have been nearly or quite zero. So the curve must have somewhere a lower limiting asymptote.

3. Between these two levels we assume that the *rate* of growth of the population, that is, the increase in numbers in any given time unit, is proportional to two things, namely:

a. The absolute amount of growth (or size of population) already attained;
b. The amount of as yet unutilized, or reserve, means or sources of subsistence still available in the area to support further population.

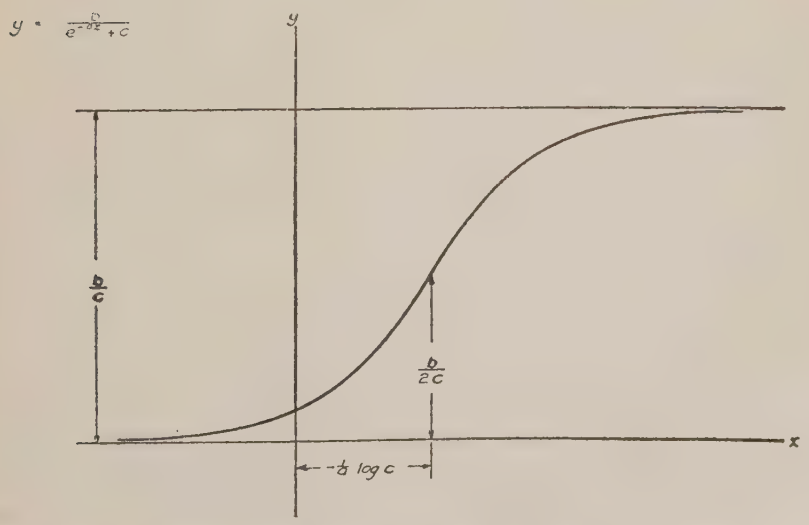

FIG. 5. SHOWING THE THEORETICAL CURVE OF POPULATION GROWTH

These hypotheses lead directly to a curve of the form shown in Figure 5, in which the position of the asymptotes and of the point of inflection, when the population is growing at the most rapid rate, are shown in terms of the constants. It is seen that the whole history of a population as pictured by this curve is something like this: In the early years following the settlement of a country the population growth is slow. Presently it begins to grow faster. After it passes the point where half the available resources of subsistence have been drawn upon and utilized, the rate of growth becomes slower, until finally the maximum population which the area will support is reached.

This theory [2] of population growth makes it possible to predict what the maximum population in a given area will be, and when it will be attained. Furthermore, one can tell exactly when the population is growing at the maximum rate. To test the theory, we have only to fit this theoretical curve to the known facts of population for any country by appropriate mathematical methods. If the hypothesis fits well all the known facts for a variety of countries in different stages of population growth, it may well be regarded as a first approximation to a substantially correct hypothesis and expressive of the biological law according to which population grows. In making this test the statistician has somewhat the same kind of problem that confronts the astronomer calculating the complete orbit of a comet. The astronomer never has more than a relatively few observations of the position of the comet. He has, from Newtonian principles, a general mathematical expression of the laws of motion of heavenly bodies. He must then construct his whole curve from the data given by the few observations. So similarly the statistician has but a relatively few population observations because census taking has been practiced along present lines only a little more than a century. According to the stage in historical development of the country dealt with he may have given an early, a late, or a middle short piece of the population "orbit" or history. From this he must construct on the basis of his general theory of "population orbits" the whole history, past and future, of the population in question.

To demonstrate how successful the population curve shown in Figure 5 is in doing this, three diagrams are presented, each illustrating the growth of the population in a different country. The heavy

[2] The mathematical hypothesis here dealt with is essentially the same as that of Verhulst put forth in 1844. As Pearl and Reed pointed out in this first paper on the subject it is a special case of a much more general law. A comprehensive general treatment of the problem we are publishing shortly in another place. The generalization in no way alters the conclusions drawn here from a few illustrative examples.

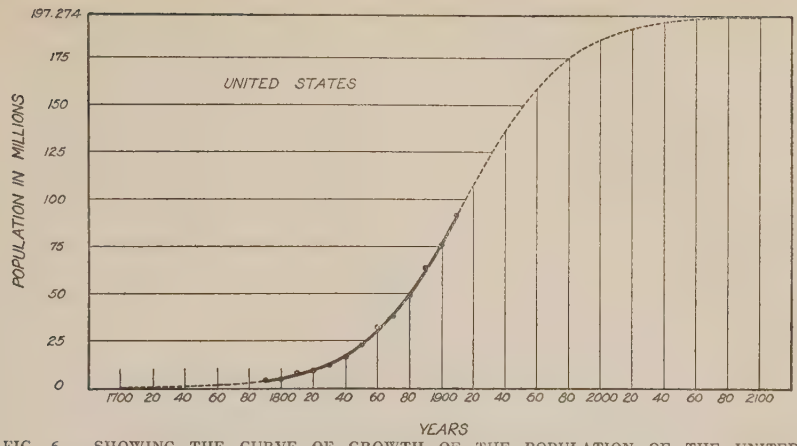

FIG. 6. SHOWING THE CURVE OF GROWTH OF THE POPULATION OF THE UNITED STATES. For further explanation of this and the two following diagrams, see text.

solid portion of each curve shows the region for which census data exist. The lighter broken part of the curve shows the portions outside this observed range. The circles show the actual, known observations. The first curve deals with the population of the United States. Here the observations come from the first part of the curve, when the population was leaving the lower asymptote. First should be noted the extraordinary accuracy with which the mathematical theory describes the known facts. It would be extremely difficult by any process to draw a curve through the observed circles and come nearer to hitting them all than this one does.

Before considering the detailed consequences of this United States curve in relation to the whole population history of the country, let us first examine some curves for other countries where the observed data fell in quite different portions of the "population orbit." Figure 7

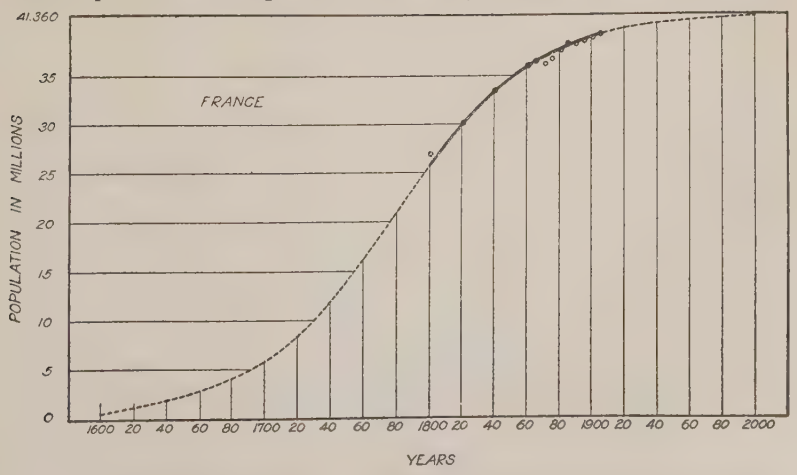

FIG. 7. SHOWING THE CURVE OF GROWTH OF THE POPULATION OF FRANCE

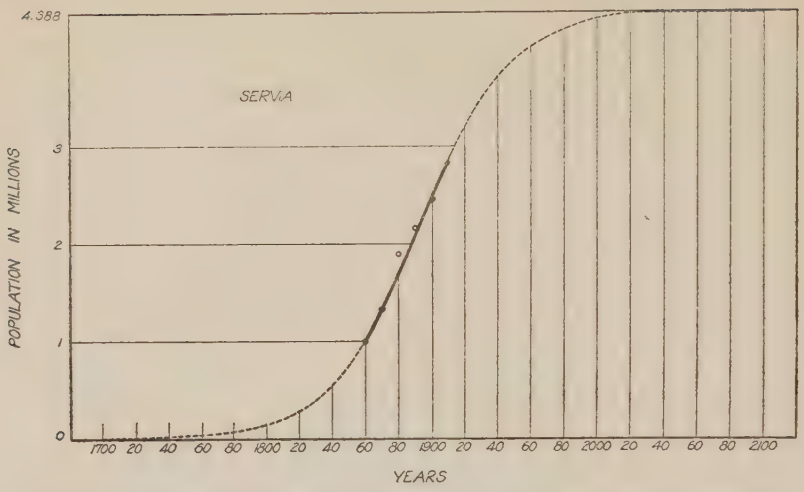

FIG. 8. SHOWING THE CURVE OF GROWTH OF THE POPULATION OF SERBIA

gives the curve for France. Since before the time when definite census records began France has been a rather densely populated country. All the data with which we had to work belong therefore towards the final end of the whole population history curve. The known population data for France and for the United States stand at opposite ends of the whole historical curve. One is an old country whose population is nearing the upper limit; the other a new country whose population started from near the lower asymptote only about a century and a half ago. But it is seen from the diagram that the general theory of population growth fits very perfectly the known facts regarding France's population in the 120 years for which records exist. While there are some irregularities in the observation, due principally to the effects of the Franco-Prussian war, it is plain that on the whole it would be practically impossible to get a better fitting line through the observational circles than the present one.

We have seen that the general theory of population describes with equal accuracy the rate of growth in a young country with rapidly increasing population and an old country where the population is approaching close to the absolute saturation point. Let us now see how it works for a country in an intermediate position in respect of population. Figure 8 shows the population history of Serbia. Here it will be noted at once that the heavy line, which denotes the region of known census data, lies about in the middle of the whole curve. Again the fit of theory to observation is extraordinarily close. No better fit by a general law involving no more than 3 constants could possibly be hoped for.

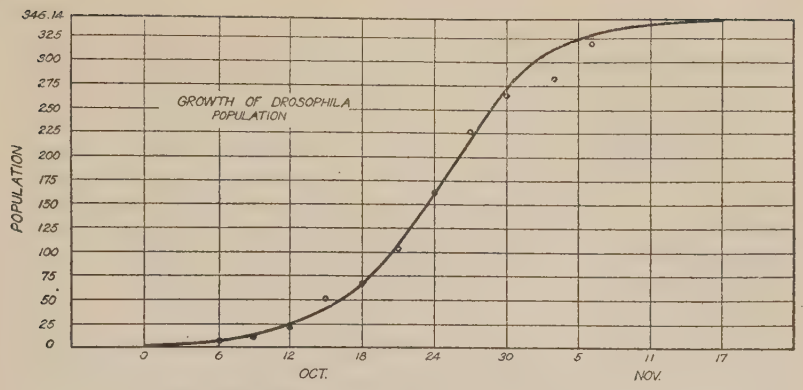

FIG. 9. SHOWING THE GROWTH OF A *DROSOPHILA* POPULATION KEPT UNDER CONTROLLED EXPERIMENTAL CONDITIONS

I think that these three examples, which could be multiplied to include practically every country for which accurate population data exist, furnish a cogent demonstration of the essential soundness and accuracy of this theory of population growth. Indeed, the facts warrant, I believe, our regarding this as a first approximation to the true natural law of population growth. We now have the proper mathematical foundation on which to build sociological discussions of the problem of population.

As a further demonstration of the soundness of this theory of population growth, let attention be directed for a moment to an example of its experimental verification. To a fruit fly (*Drosophila*) in a half pint milk bottle such as is used in experimental work on these organisms, the interior of the bottle represents a definitely limited universe. How does the fly population grow in such a universe? We start a bottle with a male and a female fly, and a small sample, say 10, of their offspring of different ages (larvae and pupae). The results are shown in Figure 9. The circles give the observed population growth, obtained by census counts at 3-day intervals. There can be no doubt that this population has grown in accordance with our law. The two final observations lie below the curve because of the difficulty experienced in this particular experiment of keeping the food supply in good condition after so long a period from the start.

Let us return to the further discussion of the population problem of the United States in the light of our curve.

The first question which interests one is this: When did or will the population curve of this country pass the point of inflection and exhibit a progressively diminishing instead of increasing rate of growth? It is easily determined that this point occurred about April 1, 1914, on the assumption that our present numerical values reliably represent the law of population growth in this country. In other

words, so far as we may rely upon present numerical values, the United States has already passed its period of most rapid population growth, unless there comes into play some factor not now known and which has never operated during the past history of the country to make the rate of growth more rapid. The latter contingency appears improbable. The 1920 census confirms the result, indicated by the curve, that the period of most rapid population growth was passed somewhere in the last decade. The population at the point of inflection works out to have been 98,637,000, which was in fact about the population of the country in 1914.

The upper asymptote given by our equation has the value 197,274,000 roughly. This means that the maximum population which continental United States, as now areally limited, will have will be roughly twice the present population. This state of affairs will be reached in about the year 2,100, a little less than two centuries hence. Perhaps it may be thought that the magnitude of this number is not sufficiently imposing. It is so easy, and most writers on population have been so prone, to extrapolate population by geometric series or by a parabola or some such purely empirical curve and arrive at stupendous figures, that calm consideration of real probabilities is most difficult to obtain. While we regard the numerical results as only a rough first approximation, it remains a fact that if anyone will soberly think of every city, every village, every town in this country having its present population multiplied by 2, and will further think of twice as many persons on the land in agricultural pursuits, he will be bound, we think, to conclude that the country would be fairly densely populated. It would have about 66 persons per square mile of land area.

It will at once be pointed out that many European countries have a much greater density of population than 66 persons to the square mile, as, for example, Belgium with 673, the Netherlands with 499, etc. But it must not be forgotten that these countries are far from self-supporting in respect of physical means of subsistence. They are economically self-supporting, which is a very different thing, because by their industrial development at home and in their colonies they produce money enough to buy physical means of subsistence from less densely populated portions of the world. We can, of course, do the same thing, provided that by the time our population gets so dense as to make it necessary there still remain portions of the globe where food, clothing material and fuel are produced in excess of the needs of their home populations.

Now 197,000,000 people will require on the basis of our present food habits about 260,000,000 million calories per annum. The United States, during the seven years 1911-1918, produced as an annual aver-

age, in the form of human food, *both primary and secondary* (*i. e.*, broadly vegetable and animal), only 137,163,606 million calories per year. So that, unless our food habits radically change, and a man is able to do with less than 3,000 to 3,500 calories per day, or unless our agricultural production *radically* increases, which it appears not likely to do for a variety of reasons which can not be here gone into, it will be necessary when even our modest figure for the asymptotic population is reached to import nearly or quite one-half of the calories necessary for that population. It seems improbable that the population will go on increasing at any very rapid rate after such a condition is reached. East, in what appears to be the most able and penetrating discussion of population of this generation, has shown that the United States has already entered upon the era of diminishing returns in agriculture in this country. Is it at all reasonable to suppose that by the time this country has closely approached the asymptote here indicated, with all the competition for means of subsistence which the already densely populated countries of Europe will then be putting up, there can be found any portion of the globe producing food in excess of its own needs to an extent to make it possible for us to find the calories we shall need to import?

Altogether, we believe it will be the part of wisdom for any one disposed to criticize our asymptotic value of a hundred and ninety-seven and a quarter millions because it is thought too small, to look further into all the relevant facts.

The relation of this already pressing problem of population to the problem of the duration of life is obvious enough. For every point that the death rate is lowered (or, what is the same thing, the average duration of life increased) the problem of population is made more immediate and more difficult unless there is a corresponding decrease in the birth-rate. Is it to be wondered at that most thoughtful students of the problem of population are ardent advocates of birth-control? Or is it remarkable that Major Leonard Darwin, a son of Charles Darwin and president of the Eugenics Education Society in England, should say in a carefully considered memorandum to the new British Ministry of Health: "In the interests of posterity it is most desirable that parents should now limit the size of their families by any means held by them to be right (provided such means are not injurious to health, nor, like abortion, an offence against public morals) to such an extent that the children could be brought up as efficient citizens and without deterioration in the standards of their civilization; and that parents should not limit the size of the family for any other reasons except on account of definite hereditary defects, or to secure an adequate interval between births."

It seems clear that the problem of population can not be com-

pletely or finally solved by limitation of the birth-rate, however much this may help to a solution. There are two ways which have been thought of and practiced, by which a nation may attempt to solve *its* problem of population after it has become very pressing and after the effects of internal industrial development and its creation of wealth have been exhausted. These are, respectively, the methods of France and Germany. By consciously controlled methods France endeavored, and on the whole succeeded, in keeping her birth-rate at just such delicate balance with the death-rate as to make the population nearly stationary. Then any industrial developments simply operated to raise the standard of living of those fortunate enough to be born. France's condition, social, economic and political, in 1914 represented, I think, the results of about the maximum efficiency of what may be called the birth-control method of meeting the problem of population.

Germany deliberately chose the other plan of meeting the problem of population. In fewest words, the scheme was, when your own population pressed too hard upon subsistence, and you had fully liquidated the industrial development asset, to go out and conquer some one, preferably a people operating under the birth-control population plan, and forcibly take his land for your people. To facilitate this operation a high birth-rate is made a matter of sustained propaganda and in every other possible way encouraged. An abundance of cannon fodder is essential to the success of the scheme.

Now the morals of the two plans are not at issue here. Both are regarded, by many people, on different grounds to be sure, as highly immoral. Here we are concerned only with actualities. There can be no doubt that in general and in the long run the bandit plan is bound to win over the birth-control plan if the issue is joined between the two and *only* the two, if its resolution is purely military in character, and if there is no international police force of a magnitude and courage adequate to cope with bandit and otherwise criminal nations. As between two nations, allowed free rein to "fight it out" by themselves without help or hindrance, the decisive element is a mathematically demonstrable one. A stationary population where birth-rate and death-rate are made to balance is necessarily a population with a relative excess of persons in the higher age groups, not of much use as fighters, and a relative deficiency of persons in the lower age groups where the best fighters are. On the contrary, a people with a high birth-rate has a population with an excess of persons in the younger age groups.

So long as there are on the earth aggressively minded peoples who from choice deliberately maintain a high birth-rate, no people can afford to put the birth control solution of the population problem into too extensive operation until such time as the common-sense of man-

kind decides that peace is in fact a more desirable state of society than war and implements this decision to practical realization through some international equivalent of a police force, which will restrain by force, and plenty of it, the activities of disturbers of the peace. "Disturbance of the peace" is not tolerated in our domestic affairs. It is no more a virtue in international relations. The only effective method which society has yet devised to secure that our home peace shall not be seriously disturbed is that of an adequate police force. There appears no insuperable difficulty in applying the same principle internationally. And any competent economist can easily show that its cost as compared with war would be extremely small. Because something of the sort is not done, one seems bound, however reluctantly, to conclude that nations as nations *prefer* wars and the opportunities for wars to a state of enduring peace. What a long way the average human intellect has still to proceed on its evolutionary pathway!

IMPENDING PROBLEMS OF EUGENICS [1]

By Professor IRVING FISHER

YALE UNIVERSITY

I feel a double sense of my unworthiness of the honor which you have bestowed upon me by electing me president of this association. On the one hand, I feel that eugenics is incomparably the most important concern of the human race and, on the other, I am painfully aware of the fact that I can bring to you no original contribution. All that I can hope to do is to point out from my viewpoint as a student of economics, and to some extent of hygiene, the opportunities which would seem to mark out some of the paths which eugenists should explore more fully.

My main thought is that there is now a golden opportunity for eugenists to "gear in," so to speak, with the great world of events. It was the dream of Galton that eugenics should not forever remain academic but that, being the vital concern of us all, it should become a sort of religion. Hitherto eugenics has been largely studied "microscopically," that is, by special technical laboratory investigations. The next step is to study it more "telescopically," that is by observations of the general facts of human history.

I do not mean, of course, that eugenists should drop their study of the inheritance of finger prints or of the inheritance of musical capacity, eye defects, skeleton abnormalities and twinning. The work of Pearson in London and of Davenport here and of their co-workers and colleagues everywhere must go on uninterruptedly. But in addition to all these, steps should be taken to organize a study of the eugenics or dysgenics of such historical events as war, immigration, colonization, prohibition, hygiene, birth control, feminism, capitalism, industrialism, democracy, socialism, bolshevism, population growth, urbanization and diminishing returns in agriculture.

It is interesting to observe in passing that these historical occurrences are due in large part to the inventions and discoveries of civilization, including especially those of rapid transportation, military science, hygienic knowledge and devices for birth control. These inventions are generally regarded as landmarks of progress. They have, thus far, undoubtedly caused progress in *economic* well-being and permitted an ever increasing *number of people* to subsist in a given area.

[1] Address of the president of the Eugenics Research Association, Cold Spring Harbor, June 24.

Mechanical inventions, particularly those which abridge distance, have given us more and more room for expansion and we have mistaken this progressive conquest of nature for a progressive improvement in ourselves. A few years ago the then president of the American Economic Association cited the increase of population as the best obtainable criterion of "progress."

But the eugenist is interested in the quality of human beings rather than their quantity, and one of the great problems to be seriously considered, is whether our boasted "progress" is not an illusion and whether after all the human race, in spite of its rapid multiplication and its increase in per capita wealth, may not be deteriorating. The discovery that this is the case would doubtless surprise and shock the country just as did the discovery that one man out of every three in our army draft was unfit. The common opinion is undoubtedly that we have made great progress and are making great progress now. The same opinion was held, so historians tell us, just before the downfall of Rome and of other civilizations which have failed.

We know that affluence often ruins men and women, and history has at least produced a strong suspicion that it was the cause, or *a* cause, of ruin of many civilizations now dead. As Goldsmith says:

> Ill fares the land to hastening ills a prey,
> Where wealth accumulates, and men decay.

The economist has shown that wealth accumulates. The eugenist may show that men decay. Dr. Pearce Bailey states that in the army examinations mental defectives amounted to two thirds of one per cent. and he concluded that a greater proportion existed in the general population.

The statistics of the feeble-minded, insane, criminals, epileptics, inebriates, diseased, blind, deaf, deformed and dependent classes are not reassuring, even though we keep up our courage by noting that the increasing institutionalization of these classes gives the appearance of an increase which in actual fact may be non-existent because institutionalization makes it possible to collect these statistics.

In Massachusettes thirty-five per cent. of the state income goes in support of state institutions and Mr. Laughlin, the secretary of this association, who compiled the government report on defectives, delinquents and dependents, estimates that seventy-five per cent. of the inmates have bad heredity. The cost of maintaining these institutions in the United States in 1915 was eighty-one millions of dollars. This takes no account of the town and county care, while all the official costs fail to take into account the cost to families and associates, the keeping back of school children by the backward children, the cost from fires of pyro-maniacs, the cost from thievery of kleptomaniacs, the cost from crime, vice, etc., of paranoiacs, maniacs and paretics and the loss of

services of able men and women drained away from other use to take care of the defectives, delinquents and dependents.

I believe that any one who has worked in these statistics with the sincere desire to get the truth has an uneasy feeling that degeneracy may be really increasing and increasing fast. Several competent students in eugenics and related fields have already reached strong convictions on the subject.

As I write, I find Professor William McDougall's new book, "Is America Safe for Democracy?" in which he says: "As I watch the American nation speeding gaily, with invincible optimism, down the road to destruction, I seem to be contemplating the greatest tragedy in the history of mankind." Research should make our conclusions on this subject beyond question. A great load of degeneracy is certainly upon us, whether it be true or not that it is increasing in weight. It is incumbent upon us to reduce it. The first step is to measure it.

There are many startling evidences of racial decay. One is that the war has damaged the potential fatherhood of the race by destroying over seven million young men, medically selected for fighting but thereby prevented from breeding. In quantity the loss of seven million men by war is not great. If numbers were really our criterion of progress we could take comfort in the fact that the world as a whole to-day has undoubtedly more inhabitants than before the war. The gap made by the war has been more than filled. This was mostly outside of Europe. In a few years Europe itself will catch up.

But small as is the number of lives lost as a fraction of population, their loss may nevertheless be the loss of most of the good male germ plasm of the nations concerned, particularly in Europe. In the United States, of course, the war has been less injurious.

Herbert Spencer, David Starr Jordan, Vernon Kellogg and others have urged with convincing force this reason for believing that war, in general, is dysgenic.

Professor Roswell H. Johnson maintains that war may sometimes be eugenic, that it is always partly so, although he has no hesitation in concluding that the recent world war has left a big net dysgenic balance.

We all agree, I think, that the destruction of seven million picked young men in their prime is not only an irretrievable loss for this generation but for all succeeding generations—increasingly rather than otherwise. A little reflection will show the argument. In the first place, to apply the argument backward, let us consider that our parents were probably above the average of their generation. This is evidenced by the very fact that they were parents. None of them died in infancy; for if they had they could not have been parents. They all had enough vitality to have gone through childhood and enough vitality and at-

tractiveness to become married and to have children. To put their supposed superiority in figures, let us, to fix our ideas, assume that they constituted the upper *fifty* per cent. of their generation. The other half of the people in their generation have left no living descendants.

Our grandparents were, in turn, presumably a still more select class of the generation in which they lived, for they not only had the vitality to become parents but, in every single case they possessed the vitality to have had at least some children strong enough themselves to become parents. These grandparents, therefore, unlike our parents were not simply the upper fifty per cent. of their generation but, let us say, the upper *forty* per cent. Some of the remaining sixty per cent. had children but their progeny ceased there and did not last to the second generation. Likewise our great grandparents were still more select, forming, let us say, the upper *thirty* per cent. of their generation, the other seventy per cent. having no descendants surviving through three generations to the present day. And so the further back we go the more select must have been our ancestors, until when we reach one thousand years back it may be that (if there were only a Eugenics Record Office to tell us) we should find, say, but ten per cent. of that generation who had left any descendants in ours. Had that ten per cent. been medically selected out and commissioned to shoot each other to death none of us to-day would be here but instead there would be the descendants of inferior stock. And that would seem to be what must happen a thousand years hence. Europe will be inhabited by the descendants of second-rate men of to-day simply because they can not be descendants of those who now sleep in Flanders Fields.

But such pessimistic conclusions are apt to be rejected as too terrible to be believed. Hope and optimism spring eternal in the human breast. Jeremiahs and Cassandras are always unpopular. If the eugenic argument against war is fallacious it should be disproved, while if it is correct it should be fortified by further research.

During the next decade there should be a wealth of statistical material on this subject, which should enable us not only to demonstrate further the truth but to bring the truth, whatever it be, home to the men and, more particularly, to the women of all lands.

It may be, of course, that the bad results of the war in other countries will be neutralized by some counterbalancing good results. It is one of the fundamental laws of human behavior to react so to an evil as to convert it into a good. We did not have safety at sea until the *Titanic* disaster had opened our eyes to the need. New York City did not have a good health department until afflicted by an epidemic. We have still reason to hope that the world war and the prospect of another, tenfold more horrible, as portrayed in Will Irwin's book "The Next War," may supply the needed stimulus to organize the

nations into an "association," or *a* league, or *the* league, to abolish war or at least to minimize, localize and control it.

And I have the further hope that the results of the eugenic research in this field, may in the not distant future, give so great an impetus to eugenics as a great social movement as ultimately to neutralize the dysgenic effect of the great war.

If nothing of the sort happens and there should be lacking the brains and energy to accomplish at least some of these things, then surely the dark ages lie ahead of us. The Nordic race will, as Madison Grant says, vanish or lose its dominance if, in fact, the whole human race does not sink so low as to become the prey, as H. G. Wells imagines, of some less degenerate animal!

With this thought in view we should perhaps shudder as well as laugh at the reflections of Clarence Day in his entertaining phantasy "This Simian World," where he observes what a different place this world would be if its masters, instead of being the descendants of anthropoid apes, were the descendants of lions or elephants, or other types of the animal kingdom!

But the obvious direct effect of war in destroying so much of the best germ plasm from which our race would otherwise be largely bred is by no means the only possible dysgenic effect of the war. Hrdlicka thinks that the roar of artillery and the other excitements of battle may make such an impression on the nervous system of soldiers as to affect injuriously their children.

Similarly there should be considered the possible effects on future generations of the undernourishment and general undercare of the children and other noncombatants who will be the parents of the next generation.

Dr. Lorenz, of Vienna, was recently quoted as saying that the average child of Vienna is about four inches below the normal height and sixteen and a half pounds below the normal weight, that thousands are suffering from rickets and not infrequently from broken bones which have given way because of their unhealthy condition.

We are apt to shut our eyes to these possibilities of race damage from the unsanitary environment and unhygienic mode of life brought about in Europe by the war because of the widely accepted dictum that acquired characters are not inherited. On this assumption we are in danger of jumping to the conclusion that the stunted, rickety or generally decrepit individuals now constituting a large part, probably a majority, of the European population will have children just as large and healthy as these particular parents could have had under ordinary circumstances. We are severely told that rickets and broken bones are not inherited.

Conklin says: "How could defective nutrition, which leads to the

production of rickets, affect the germ cells, which contain no bones, so as to produce rickets in subsequent generations, although well nourished?"

But granted all this as "gospel truth," its complacent application to the existing European conditions would be altogether unjustified and misleading.

Conklin himself, on the very next page after that from which I have quoted, expresses an important qualification. He says "that unusual conditions of food, temperature, moisture, etc., may affect the germ cells so as to produce general and indefinite variations in offspring is probable, but this is a very different thing from the inheritance of acquired characters."

For our present purposes, however, the difference is small and the similarity great. If the depleted vitality of Europe is to show in future generations it is just as much depletion whether general or specific, whether the rickets of this generation will be followed in the next by rickets or by tuberculosis or neuro-pathic conditions or feeble-mindedness or any other manifestation of damage done. From a practical point of view the question is whether damage to the present generation will still be damage in succeeding generations, and not the technical question of whether the specific form of that later damage will be the same as of the present damage. Biologists are in danger of deluding themselves by clinging to form rather than substance in this instance however technically correct is the insistence that acquired characters are not inherited.

In this insistence they often give the impression, if in fact they do not receive it themselves, that the sins and misfortunes of this generation are not visited on the next. Observations and experiments on the mutations of the primrose, of yeast and of insects indicate that environment often does leave permanent marks on the species. Gy in France has found that tobacco not only damaged the animals on which he experimented but their offspring as well. Van der Wolk found that maple trees injured by bacterial infection (rot) gave rise to leaves of a changed color and to flowers which, unlike the original, were monosexual; also that these changes were transmitted. The bacterial infection thus originated a new species!

One great field, therefore, for eugenic research is the study of the extent to which future generations are damaged because of damage received by their parents of the present generation, in other words the extent to which hygienic or unhygienic conditions for the individual are eugenic or dysgenic for his offspring—in short, the extent to which hygiene is eugenic.

If it be true, as I have little doubt, that the recent unhygienic conditions of war are sure to crystallize into permanent dysgenic condi-

tions of peace, it is, by the same token, also true that in general and quite irrespective of the war eugenics must take account of hygiene.

Now if what is poison to the individual is in general poison to the race, if what helps or hurts the individual in his own life leaves, to some extent, a beneficial or harmful impress on posterity, then the importance of eugenics is greatly extended and it becomes a task of eugenic research to study the extent to which the indiscretions and bad environment, on the one hand, or the good habits and good environment, on the other, affect our descendants. And it becomes a mission of the eugenics movement to discover and set itself against race poisons. These may include not only alcohol, habit-forming drugs and infections but, if Gy is right, tobacco and, if Kellogg is right, even tea and coffee. We have no right, in the present state of our knowledge, to assume that these are harmless to the race, if they are harmful to the individual.

I would emphasize this partly because, so far as I have any right at all to speak as a eugenist, it is on account of studies in the neighboring field of hygiene.

Civilization has thrown the daily life of the individual out of balance, so that not one person in a hundred lives what might be called a biologic life. He is insufficiently exposed to the air, he eats too fast and often too much. In America he eats far too much protein and far too little bulk. His food is far too soft. It is usually lacking in vitamines. His evacuations are too infrequent, his posture is usually abnormal and unhealthful. His activities are too one-sided. His mind is too excited, worried and hurried. Worst of all, he is the unconscious victim of many physical poisons and infections. The examinations of the Life Extension Institute show some physical imperfections in practically every person examined. And the average man is blissfully unconscious of the damage he thus does himself, cumulatively, day after day and year after year. Yet this damage keeps on like a creeping fire under the leaves in the woods.

Hygiene and eugenics should go hand in hand. They are really both hygiene—one individual hygiene and the other race hygiene—and both, eugenics—one indirectly through safeguarding the quality of the germ plasm and the other directly through breeding.

I do not mean to assert that hygiene, as practiced, is necessarily eugenic. It may well be true that *misapplied* hygiene—hygiene to help the less fit—is distinctly dysgenic. I remember being astonished at the attitude of a university president, who became very enthusiastic over the triumph of hygiene saying, "I know of a girl who had many disabilities. She had a surgical operation to remedy one difficulty and a course of hygiene to remedy others, so that finally she was so repaired and improved as to be converted into quite a respectable human being

and now she is married." Schools for tubercular children give them better air and care than normal school children receive. Institutional care of defectives often surpasses that in the home.

Eugenic research can help the eugenic cause by showing the folly of such differential care of the biologically unfit, especially when such differential care is not accompanied by safeguarding against the marriage of the unfit. Undoubtedly the rule of eugenics should be "to those that have shall be given" and this maxim will have added eugenic worth the more it can be shown that biologic gifts belong not only to the present generation, but to all that come after.

The picture of this world and especially of Europe suggested to our minds by what has thus far been said is that population is increasing in quantity but declining in quality.

At present the world contains seventeen hundred million people and, according to Professor East, its population is increasing by about fifteen millions per annum. It is fast filling up the empty spaces of the globe. The rapid filling up of North America during the last century will surely be followed by the filling up of South America and Africa in the next century.

In a few generations as Thompson and East emphasize, the expansion in numbers must itself approach an end. Within the life time of many living there will, in all probability, come a realization such as at present scarcely exists of the profound truths set forth by Malthus at the beginning of the nineteenth century. We must not be deceived by the exceptional conditions under which we have been living in the last two or three centuries. The opening up of America gave a new outlet for population and reduced and postponed the operation of Malthus' checks to population. Mechanical inventions, which increased physical productivity, had the same effect. But after the lands now empty are full and those now waste are reclaimed no increase of the food-producing area of the globe is conceivable. Nor is it likely that inventions which have made two blades of wheat grow where one grew before can go on at a geometrical progression and so keep pace with the biologically possible growth of population. And unless this be possible population must necessarily in a few generations come practically to a halt, either by the relentless check of an increased death rate or by the more preventive check of a decreased birth rate.

What will be the eugenic significance of this future limiting of population? This is one of the great questions for eugenic research. The answer will doubtless depend largely on which of the two checks will be put on population, whether it is to be the check from an increased death rate operating through lack of subsistence or the check from a decreased birth rate operating by volition of parents.

The former check shown by Malthus led Darwin to conceive his

theory of natural selection, which in turn led Galton to suggest eugenics.

In so far as the future check on population is to be of this kind, even though an increased death rate involve much misery, the presumption is that, on the whole, it will be eugenic rather than dysgenic in its effects. Those should survive who are best fitted to earn a livelihood. But this is, as the critics of Malthus complained, a dismal outlook.

The operation of the other check is not so obvious. To-day we have, in a way and to a degree of which Malthus probably never dreamed, the exercise of this prudential check under the title of neo-Malthusianism or birth-control.

Until recently this subject was not discussed in the open, partly because the movement had not gained sufficient momentum, partly because of the conventional reticence on all matters of sex and partly because of the continual existence (in this country alone among the nations of the earth) of laws passed at the instigation, chiefly, of Anthony Comstock, forbidding the dissemination of information on birth-control.

But the subject is one especially deserving eugenic research; for, of all human inventions, those relating to birth-control probably have the most direct bearing on the birth rate and its selective possibilities.

It is startling to think that the sex impulse which hitherto has been the unerring reliance of nature to insure reproduction can no longer be relied upon. Some insects sacrifice their lives to reproduction. Nature relies on their blind instinct to reproduce regardless of any consequences to themselves. If we could suppose such an insect suddenly to be given an option in the matter so that it could satisfy its sex impulse without the consequences of offspring or of immediate death to itself, its instinct of self-preservation would presumably refuse to make the ancient sacrifice and the species would perish from off the earth.

In the case of the human species nature demands no such extreme sacrifice of the mother; if this were the case birth control would almost surely mean the ultimate extinction of the human race. But the human mother has nevertheless had to sacrifice personal comfort and both parents have had to sacrifice some economic well-being and some social ambitions to meet the obligations of parenthood. Hitherto the only effective ways to avoid this and still satisfy the sex instinct have been infanticide and abortion. Birth-control offers another way, easier, less objectionable and therefore destined to be far more widely practiced among civilized peoples.

This is largely a development of "feminism" in the interests of women. It opens up amazing possibilities of race extinction or, on the other hand, of race betterment.

If the birth-control exercised by individual parents could itself be controlled by a eugenic committee it could undoubtedly become the surest and most supremely important means of improving the human race. We could breed out the unfit and breed in the fit. We could in a few generations and, to some extent even in the life time of us of to-day conquer degeneracy, dependency and delinquency, and develop a race far surpassing not only our own but the ancient Greeks.

Thus birth-control is like an automobile. It can convey us rapidly in any direction. As now practiced which way is it carrying us? Where will birth-control really take us? This is a matter for eugenic research to settle. There are three possibilities: (1) it may cause depopulation and ultimately bring about the extinction of the human race; (2) it may reduce the reproduction of the prudent and intelligent and the economically and socially ambitious, leaving the future race to be bred out of the imprudent, unintelligent and happy-go-lucky people, thus resulting in race degeneration; or (3) it may cut off the strain of the silly and selfish, the weak and inefficient who will dispense with children for the very good reason that they lack the physical stamina or the economic ability to support a large family.

The advocates of birth-control maintain, with much show of reason, that it diminishes poverty, increases efficiency, prevents damage to the mother's health, and improves the health and education of the children.

What does history tell us so far? The best opinion seems to be that in Holland birth-control has reduced infant mortality by making better intervals between successive children and by increasing their size and vigor as well as the per capita wealth of the country. In countries where birth-control has been exercised only a short time the reduction in the total number of births has been accompanied by an almost equal reduction in the total number of deaths. There is a distinct correlation between the death rate and the birth rate so that a moderate amount of birth-control need not reduce much, if at all, the rate of increase of population. In Russia, Roumania, Bulgaria and Serbia, presumably without birth-control and where the birth rates are forty or fifty per thousand, there is an increase of population between fifteen and twenty per thousand, and in Australia and New Zealand, with birth control and where the birth rates are from twenty-five to thirty per thousand, there is substantially the same rate of increase. When birth-control in these last named countries has been in use longer and more generally the same effects as in France may perhaps be expected. In France population was actually declining before the war, a situation realized in no other country, except in the time of the World War, when it was temporarily true of England, Serbia and some other countries.

It is worth noting here that if feminism is to have a depopulating effect the first element it will extinguish is the feminist element itself.

So far as it elevates woman, feminism is to be commended. But friends of womankind should heed well the warning of some other movements which contained the seeds of their own destruction. "Shakerism" killed itself because it shunned marriage. Feminism may kill itself if it shuns children. A bragging feminist recently referred to the old child-bearing women as a type which has disappeared below the historical horizon. If it has, then the type which will not bear children will surely disappear in its turn just because it will have no children in its own image.

The world's experience with birth-control thus far does seem to show that the average family which practices it does not practice it in the required moderation. Dublin has shown that, under present conditions, it takes an average of about four children in the family for the upkeep of population. An average of three means decrease of population and an average of five means increase of population.

But aside from the danger of depopulation as shown in France is the question of the kind of selective birth rate which birth-control will bring about. Will this be a good or a bad selection? As birth-control leaves births to human choice instead of to instinct, many jump to the conclusion that this is necessarily a step forward. But whether it is or not depends on how this human choice will actually operate.

Professor McDougall has given reason to believe that the present occupational stratification of society corresponds roughly to the stratification of intelligence; that the four classes, (1) professional men and business executives, (2) other business men, (3) skilled workmen and (4) unskilled workmen represent on the whole four classes of human beings graded as to innate mental ability. The college graduate means the professional man and business executive.

Cattell finds that the average Harvard graduate is the father of three-fourths of a son and the average Vassar graduate the mother of one-half of a daughter and that the average family of American men of science is only 2.22 as compared with an average of 4.66 for the country. Popenoe and Johnson give similar results summarizing many statistical studies of Yale, Harvard, and other educational institutions.

At present, then, our educational system seems to be destroying the very material on which it works! Colleges seem to be engines for the mental suicide of the human race! Are the colleges of to-day sterilizing our scholars as did the monasteries and nunneries of the middle ages? Such race suicide of scientific and educated men and of the well-to-do classes means that their places will speedily be taken by the unintelligent, uneducated and inefficient.

Up to the present time, so far as I can see, birth-control has done harm to the race, exactly in the same way as has the war.

But it is plain that the extension of birth-control to all classes will tend to rectify this condition. At present it is practiced only in the

upper one or two of the four strata which McDougall distinguishes in his statistics. Its extension is rapidly going on, thanks to the propaganda of Sanger, Drysdale and others and will inevitably include all classes eventually. It is therefore too early to condemn utterly birth-control. It may still prove to be a great instrument for eugenic improvement.

It will probably require long years of research to determine what the ultimate effect will be. The hypothesis which now seems to be probable is that there will be three stages.

The first effect of birth-control seems, as has been said, distinctly bad because it is first practised by the intelligent class and is, for that class, as Mr. Roosevelt said, "race suicide."

The second effect will be that where birth-control is practised among all classes, as has almost been the case in France, an actual decline in population will occur which will seem alarming.

The third effect may then follow. It is a rapid repopulation from the small minority of the strongest, most efficient, and the most child-loving and altruistic persons of the population. We all know people who, though fully aware of the possibilities of birth-control, nevertheless do not practise it or do not practise it to excess, but rear large old-fashioned families because they love children, can afford to have them, and have no physical or economic difficulties in bearing and raising them. These vigorous champions of humanity will doubtless possess not only physical strength but the intelligence necessary to earn a sufficient livelihood to justify their choice of having large families.

Whenever civilizations have decayed, and many probably have done so from race suicide, their places have been taken by strong and fecund invaders. In the case of birth-control the invasion need not come from outside. It may come from inside the decadent nation itself. It is said that, in this way, the Breton portion of the French population is replacing the other portions. Multiplying by geometrical progression, a tenth part of our population can in a few generations of large families fill up all the gaps made by birth-control and make a stronger race than we ever have had. Should this rosy prospect actually work out in the twenty-first or twenty-second century, birth-control would go down in human history, like the flood in the Bible, as a means first of wiping out the old world and then replacing it by a new, from the best seeds of the old.

At any rate, while there are undoubtedly grave possibilities of evil facing us in birth-control, we must not be misled by averages. The *average* Harvard graduate may not reproduce his kind, but among thousands of college graduates there will almost certainly be found a *few* who do and by geometrical progression the few can become the majority.

An apparent objection to this forecast is that the most reckless will practice birth-control the least and so will have the greatest number of children. But this objection may possibly be answered by the fact that such people will soon become public charges, as paupers for instance, and that we may then stop their reproduction by enforcing celibacy, segregating the sexes.

But the truth is that we can not yet tell what will ultimately happen as the net result of birth-control, whether race degeneracy, depopulation, or race improvement or, as I have suggested, all three in succession.

One of the claims of enthusiastic advocates of birth-control is that it will help save us from further war because it will save us from that pressure of population which results in imperialistic ambitions. Huxley and others are quoted to support the view that pressure of population and the need of an outlet for surplus population lie behind emigration, colonization, conquest and war. It is inferred that the real remedy for the yellow peril or the "rising tide of color" must consist in the extension of birth-control to the Orient. How much truth there is in this view is a matter for eugenic research to determine. The same argument for extending birth-control to other nations applies as for extending it to other races within our own.

At present the white race is still increasing faster than the other races but it is easy to see that birth-control will soon put an end to this unless birth-control is extended from the white race to the colored. Birth-control, war and immigration are certainly associated problems.

Economically, immigration of cheap labor is beneficial (initially at least) to capital and injurious (initially at least) to native labor. The conflict between these two interests, of capital and of labor, constitutes most of what is ordinarily included in the immigration problem.

The core of the problem of immigration is, however, one of race and eugenics, despite the fact that in the eighteen volumes of the report of the Immigration Commission scarcely any attention is given to this aspect of the immigration problem. If we could leave out of account the question of race and eugenics I should, as an economist, be inclined to the view that unrestricted immigration, although injurious to some classes, is economically advantageous to a country as a whole, and still more to the world as a whole. But such a view would ignore the supremely important factors.

The character of the present immigration will make a great difference in the character of our future inhabitants.

Between 1788 and 1840 England sent many of its undesirables to Botany Bay, near Sydney, Australia, and to-day the excessively large slums of Sydney are, according to the findings of Dr. Davenport, to a large extent the progeny of those undesirables. At present the United

States inherits, both socially and biologically, probably as much from the eighty thousand original immigrants, who, Benjamin Franklin said, had come to this country up to 1741, as from all the other immigrants since that time. Our problem is to make the most of this inheritance. We can not do so if that racial stock is overwhelmed by the inferior stock which "assisted" immigration has recently brought.

If we allow ourselves to be a dumping ground for relieving Europe of its burden of defectives, delinquents and dependents, while such action might be said to be humane for the present generation, it would be quite contrary to the interests of humanity for the future. Not only should we be giving these undesirable citizens far greater opportunity to multiply than they had at home, but we would be taking away the checks on the multiplication of those left at home. It would be a step backward, a step towards populating the earth with defectives, delinquents and dependents. That the foreign born multiply faster than the native stock has been shown by the Immigration Commission and by East, Dublin, Baker and others. There is great danger, therefore, not only to this country, but to the whole world, of injuring the germ plasm of the human race by the indiscriminate immigration of recent times. The best service we can render, not only to ourselves, but in the end to those very nations which would feign empty their almshouses, asylums and prisons on us, is to prevent their doing so. In the words of Professor Ross in "The Old World in the New":

> I am not of those who consider humanity and forget the nation, who pity the living but not the unborn. To me, those who are to come after us stretch forth beseeching hands as well as do the masses on the other side of the globe. Nor do I regard America as something to be spent quickly and cheerfully for the benefit of pent-up millions in the backward lands. What if we become crowded without their ceasing to be so? I regard it (America) as a nation whose future may be of unspeakable value to the rest of mankind, provided that the easier conditions of life here be made permanent by high standards of living, institutions, and ideals which finally may be appropriated by all men. We could have helped the Chinese a little by letting their surplus millions swarm in upon us a generation ago; but we have helped them infinitely more by protecting our standards and having something worth their copying when the time came.

What has been said applies to immigration even from countries of our own race.

The problem of Oriental immigration has a somewhat special character. It involves race prejudice and impossibility of assimilation, socially and racially. The arguments usually brought forward in this connection are largely partisan and inconsistent. The Japanese immigrant in California is hated as belonging to an inferior race, on the one hand, and, on the other because his industry, frugality and intelligence are such that the native laborer can not compete with him. In other words he is hated both because he is inferior and because he is superior.

Of him I would say, as of immigrants generally, that from a narrow, shortsighted economic point of view, his immigration should be encouraged, but if we should let down the bars for Oriental immigration, under modern conditions of rapid transportation, the country might be inundated with Chinese, Japanese and Hindoos. We should then lose even that modest degree of political solidarity which we now possess. There would probably be a demoralization and disintegration of our general social structure and, what most concerns us, we should add to our present southern and black race problem a western and yellow race problem; race wars, lynchings and massacres, such as we have just been witnessing would ensue. Ultimately, if not speedily, actual war with a United Asia would undoubtedly be brought about. What Japan has done in one generation, China can do in the next. And when China is fully equipped with battleships, machine guns, aeroplanes and poisonous gases, she and Japan could possibly conquer the whole white world.

We have often laughed at the yellow "peril" especially when it was the nightmare of the Kaiser. But later he showed us what peril may be in even one comparatively small nation. To-day the yellow color peril is the subject of a seriously alarming book by Lothrop Stoddard, "The Rising Tide of Color." It is in the thoughts of many far-seeing people on the Pacific coast. Under unrestricted immigration, within a century a majority of this country might become Oriental, especially if we commit race suicide. It would require only a few years for millions to enter and by geometrical progression it requires only a few generations for millions to become scores or hundreds of millions.

What has been said is from the point of view of our own white race and American nationality. Theoretically and academically it may be that true eugenics for the human race as a whole may favor some other race than ours, and that, say, yellow domination rather than white domination, may, in some distant future, be the ideal domination. But we can not be expected, especially in the absence of any proof that we are an inferior race, to act on that assumption and quietly lie down and let some other race run over us.

Again, it is possible that the ideal for remotely future ages may be a human race which is a mixture of all existing human races. That is also a subject for eugenic research. The solution, for instance, of the Jewish problem, if such exists, may be their racial assimilation. But if such a mixture is ever effected, especially a mixture of widely different races, it must come slowly. We can not ignore race prejudice, and any sudden mixture is sure to produce an unstable compound, which will blow up in race war and social demoralization. Professor East believes that the black and white mixture in Africa will be one of

the greatest of race problems three generations hence. The obvious safeguard at present is restriction of immigration of a drastic kind. This should be done tactfully and reasonably. As Stoddard points out, if the white world does not wish to be dominated by the world of color it ought to cease its own attempts at dominating the latter.

Of the great problems which I mentioned at the outset, I have sketched briefly the problems of war, hygiene, birth-control and immigration in their relations to eugenics.

The results of a cursory bird's eye view seem to indicate that much of what we call progress is an illusion and that really we are slipping backwards while we seem to be moving forwards. Human ambitions under the opportunities afforded by civilization seem to sacrifice the race to the individual. We congregate in great cities and pile up great wealth but are conquered by our very luxury. We seek imperial power and not only damage but destroy our germ plasm in war. We seek social status and education but limit motherhood. Like moths attracted by a candle, we fly toward the glamour of wealth and power and destroy ourselves in the act.

In concluding this telescopic review of big eugenic problems, I may be permitted to point out the directions in which it seems to me we may hope for remedies.

If it be granted that war is dysgenic, then a League or Association of Nations which will prevent or minimize war is an important eugenic device.

If it be true that birth-control among the intelligent is due, to a certain extent, to the fact that children are an economic handicap, Professor McDougall's suggestion of putting an economic premium on large families among the fit ought not to be overlooked. A millionaire like Carnegie, instead of pensioning professors or rewarding heroes, might subsidize children among a specific group of biologically fit to be determined by a committee of award. Ultimately when public opinion is ripe, the government might subsidize the children of school teachers also instead of, as is at present sometimes the practice, discharging women school teachers if they marry.

Coeducation in colleges ought not to go unmentioned as promising somewhat to increase the marriage rate among college graduates.

Segregation of the sexes in public institutions is a eugenic device of undoubted value. It does no violence to our humanitarian ideas to take care of the present crop of undesirables on condition that they shall not act as seeds for future crops.

If it be granted that, from our standpoint at least, indiscriminate immigration is dysgenic, a discriminating exclusion must be eugenic. Laughlin's proposal of having aliens examined in their home town for mental and other defects is full of promise. The proposal of registra-

tion of immigrants and then deporting and purging the country of the most undesirable among them as soon as these undesirables turn up later at feeble-minded and other institutions is likewise full of promise.

Doubtless much can be added to this meager program as a consequence of eugenic research and some things may be subtracted from it.

But, in order to lead to anything practical and effective eugenic research must be followed by, and in fact accompanied by, some far-reaching publicity. I mean that there must be a diffusion of the knowledge gained and, what is far more important from the standpoint of securing action, a diffusion of a sense of the pre-eminent importance of eugenics. Finding ourselves in the shadow of the Great War, in a world damaged by that war and by the other causes of degeneracy which have been mentioned, we can not stand silently by and see the general public enjoying a fool's Paradise. In the bliss of ignorance they mistake economic production and expansion for genuine progress and, with the best of intentions are, we fear, paving the road to hell.

There are millions of people in the world to-day whose enthusiastic support for eugenics could probably be obtained at the price of a little publicity. We now have a golden opportunity that should not be missed.

One means of enlightening the public is through increasing interest in hygiene, especially individual hygiene. Charity begins at home and, psychologically, the only route to race hygiene is through individual hygiene.

The teaching of both hygiene and eugenics in schools and colleges merely enough to show the elements of both, including the Mendelian principles of heredity and the responsibility of each person to the race, will appeal alike to self interest and to that idealism which is always present in young people whose lives lie ahead of them. Just as the Catholic church proselytes by getting children at the formative age, just as prohibition got its grounding in the public schools, so hygiene and eugenics can become the life-long possession of the next generation if inserted in the school books of the present generation.

In our public schools should also be included educational and mental measurements. They are rapidly coming into use in our colleges and universities throughout the nation. They emphasize individual differences and will serve to correct the view that "men are created equal" in the biological sense while leaving them equal in opportunity before the law.

We may hope that the proposed national Department of Public Welfare will spread knowledge in regard to scientific "humaniculture" as knowledge of scientific agriculture has been spread through the Department of Agriculture.

Another vehicle or starting point which should not be forgotten is

the coming International Congress of Eugenics in the fall. Extraordinary pains should be taken to see that the newspaper, magazine and moving picture publicity in regard to that congress may be adequate and effective. This congress should be followed up by an organized movement for general publicity on eugenics. This may, or may not, be the proper function of the Eugenics Research Association. If it is not, a new association should be started as a go-between to connect scientific research with the public.

Needless to say, in any propaganda care must be exercised to prevent the hasty endorsement of unproved methods and theories. But there is ample basis already for a movement the initial purpose of which will not be so much a detailed specific program as a general spread of the idea that eugenics is the hope of the world. Details can wait. Where there is a will there is a way and without a will there is certainly no way at all. While eugenic science is painfully finding the way there is ample work for a propaganda organization to secure the will.

I believe in Galton's idea that eugenics must be a religion. It will prove a wonderful touchstone by which to distinguish between what is racially and radically right and what is racially and radically wrong. It will bring home to parents the thought that much, if not all, of their conduct may be fraught with future significance for their children and children's children. It will throw its searchlight into every nook and cranny in the life of the individual and of society.

Therefore it will help mould all human institutions. Especially will it help mould that fundamental institution, human marriage. While marriage is a most intensely individual and private matter, it has been regarded, from time immemorial, as of vital concern to society. Around this great institution of human marriage have always clustered many sorts of folkways. In civilized times the law has made legitimate marriage a binding contract and religion has given it its divine blessing. It now remains for science which in so many other ways is remodeling the whole modern world, to affix its seal of approval.

And just as law and religion discriminate and refuse their seal of approval to alliances which are found to be improper from their respective viewpoints, so must science discriminate. Dysgenic marriages must be discountenanced just as bigamous or incestuous marriages are discountenanced.

In thus withholding or giving a coveted approval eugenic science will elevate marriage in its way as greatly as have law and religion in theirs. It will shed the light of reason on the primeval instinct of reproduction. It will exalt what is already a "legal contract" and "holy matrimony" into a dedication of all we are to what we want posterity to be.

A FEW QUESTIONABLE POINTS IN THE HISTORY OF MATHEMATICS

By Professor G. A. MILLER

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MOST of the professional mathematical historians have been basement builders and many of our general histories of mathematics remind one of the church buildings which consist of a basement roofed over while funds for completing the structure are being awaited. In some cases, such as Cantor's noted *Vorlesungen über Geschichte der Mathematik*, the basement is not even roofed over.

In fact, the work of Cantor might remind one in a mild way of the following statement in the Scriptures: "This man began to build and was not able to finish." If it is true that about *fifteen* volumes would be required in order to cover the developments of the nineteenth century as completely as Cantor covered the period up to the beginning of this century, as is suggested in the preface to Volume 1 of Dickson's "History of the Theory of Numbers," 1919, it results that Cantor did not complete one-fifth of the job of writing a general history of mathematics up to the end of his scientific activity.

It seems questionable whether a basement history, even when the basement is roofed by slight attention to the developments of the nineteenth and the twentieth centuries, is the most suitable history to place in the hands of the young student. Present day activities in mathematics have received entirely too little attention even on the part of the students who specialize in this subject.

A considerable number of questions in the history of mathematics have been answered differently by different writers and hence this subject offers unusual opportunities for the exercise of judgment and for argumentation. To some this may appear to be an attractive feature since disputation has long been recognized as a useful educational exercise and elementary mathematics presents comparatively few questions to which different answers have been given by good recent writers. Hence the student of this subject is inclined to confine his attention too closely to questions which can be answered definitely.

It is not the object of the present paper to give a definite answer to some of the questions which have been in dispute for a long time but rather to direct attention to a few more questions which seem to be

open to dispute, in the hope that the interest in these questions may thereby be increased and the interest in the history of our subject may thus be fostered. In the main the present writer will present here arguments exhibiting a point of view which is not in accord with the one presented in the second edition of Cajori's "History of Mathematics," 1919, and our references to pages relate to this work.

On page 142 it is stated that "the foremost French mathematician before Vieta was Peter Ramus (1515-1572), who perished in the massacre of St. Bartholomew." It can not be assumed that the fact that Ramus perished during the massacre of St. Bartholomew constitutes a a claim to mathematical fame since thousands of others were then slain, but one consults the index of Cajori's history in vain for other reasons for calling Ramus the foremost French mathematician before Vieta.

It is interesting to note that in the history of many a country there is a record of some mathematician who is very much better known than any of his predecessors in the same country. As instances we may cite Newton in England, Leibniz in Germany, Napier in Scotland, Abel in Norway, etc. In some cases very little is known about any of the predecessors of such a man in the country in question. For instance, G. A. Gibson stated that before Napier (1550-1617) Scotland made not a single contribution to mathematical science [1]. In case more is known about the predecessors of such a man it is a question of some interest to inquire into the relative merits of their contributions.

Hence one is naturally interested in knowing something about the work of the French predecessors of Vieta who is doubtless much better known than any of these predecessors. Among these there are, in addition to Ramus, such favorably known men as N. Oresme and N. Chuquet. The reader who recalls the many references to the works of the last two mathematicians (e. g., on page 14 of tome 3, volume 3, of the "Encyclopédie des Sciences Mathématiques" G. Eneström notes that a work by Oresme serves as a graphic preamble to the introduction of analytic geometry) will naturally wonder why Ramus is placed ahead of them in both editions of Cajori's "History of Mathematics."

It is true that Ramus is better known in general than Oresme or Chuquet, but Ramus is known principally on account of his attacks on the accepted views of his day and not on account of his contributions towards the advancement of mathematics. In mathematics he also exhibited his quarrelsome disposition but he failed even to understand the more subtle points involved in some of the mathematical methods which he attacked. He emphasized the importance of teaching the practical methods of calculation employed by the merchants of the street and his mathematics was of the business college type rather than of the university type.

1 "Napier Tercentenary Celebration Handbook," 1914, p. 2.

His contention that the method of giving a collection of definitions first, as is done in Euclid's "Elements," is unnatural since a forest was not created by growing the roots of the trees first may have had considerable influence on later textbooks on elementary mathematics. It is, however, a question whether a quarreling and quarrelsome dialectician, such as Ramus was, should be placed ahead of Oresme and Chuquet as a mathematician even if his activities had a wholesome influence on mathematical instruction and may have been largely responsible for the early and radical departure from Euclid's "Elements" on the part of French textbooks on geometry.

As the names of Oresme and Chuquet are prominent in the history of exponents in elementary mathematics, the former having used fractional exponents and the latter the exponent zero, their work naturally calls in question the following statement found on page 149: "It is one of the greatest curiosities in the history of science that Napier constructed logarithms before exponents were used." The notion of exponents and not the formal use of them in the modern way is related to the development of logarithms, and this notion was much older even than the work of Oresme, who lived more than two centuries before Napier.

In view of the great mathematical influence of the Ecole Normale of Paris it may be of interest to refer to the statement found in various places to the effect that its first students were young pupils. For instance, on page 256, it is stated that "at the establishment of the *Ecole Normale* in 1795 in Paris, he (Lagrange) was induced to accept a professorship. Scarcely had he time to elucidate the foundations of arithmetic and algebra to young pupils, when the school was closed."

While the term "young pupils" is not very definite, yet few people would be likely to associate it with students whose ages varied from 21 to 66. In fact, according to "Le Centenaire de l'Ecole Normale," 1895, page 125, nearly half of these "young pupils" were from 30 to 60 years old, and among them was Bougainville, a celebrated navigator, who was 66 years old. The law prescribed that none of these students should be less than 21 years old but it did not fix an upper limit to their ages as the best prepared available students were desired.

In view of the great influence which this ephemeral experiment had on the teaching of mathematics and other sciences in the secondary schools of France and the fact that the professors of mathematics (Lagrange, Laplace and Monge) were eminent mathematicians, it is of interest to know that these early students, who were paid to come to Paris from various parts of France, were not "young pupils" in the sense in which this term is commonly understood, but were, in the main, mature men who could derive much profit from a profound presentation of the elements of various educational subjects. Some of

Lagrange's lectures prepared for these students were translated by T. J. McCormack and published in 1901 under the title "Lectures on Elementary Mathematics by Joseph Louis Lagrange," The Open Court Publishing Company.

It may be noted here that the official journal of this normal school during the first brief period of its existence was entitled *Séances des Ecoles Normales,* and not *Journal des Ecoles Normales* as is stated in various places including the *Encyklopädie der Mathematischen Wissenschaften,* volume 3, page 519, and on page 274 of the history noted above. In the latter work we find also on page 204 the title *Transactions of the London Mathematical Society* instead of *Proceedings* of this society. In this case the title is the more misleading since the number of the volume is also incorrectly stated as 20 instead of 22.

It is true that the said *Séances* really were a journal and the said *Proceedings* really involve what is commonly called transactions, but the work of the beginner is apt to be greatly increased by a failure to give exact references and it is the beginner who should be especially encouraged to look up references. If such a reader fails to find a journal which bears the exact title given in the reference he seldom looks further.

While a study of the history of mathematics doubtless tends towards the formation of clearer mathematical concepts it is evidently necessary for the student of this history to distinguish carefully between the good and the bad in ancient methods. Some of the ancient methods which may appear to be praiseworthy for the time when they originated would be questionable and perhaps even intolerable if they were used in our modern textbooks. Possibly the ancient Greek proof of the fact that $\sqrt{2}$ is not a rational number belongs to this category since it is special and does not appear any easier than the following more general proof, which is based upon the elementary fact that if a rational fraction is reduced to its lowest terms than every integral power of this fraction is also in its lowest terms.

Suppose that $\sqrt[n]{m}=c/d$, where c/d is reduced to its lowest terms and d is not equal to 1. By raising both members of this equation to the n^{th} power it results that $c^n/d^n=m$, and since c^n/d^n is reduced to its lowest terms m can not be an integer. This known proof establishes at one stroke the existence of an infinite number of irrational numbers if we assume the existence of at least one real n^{th} root of every positive integer. To the extent that a knowledge of the history of mathematics leads us to prefer old historic methods to equally simple more general methods it is positively injurious.

Young teachers who study the history of mathematics with the laudable purpose of increasing their efficiency in the class-room should

bear in mind that there are exceptions to the rule that the mathematical development of the student is similar to the mathematical development of the human race. The modern student can not afford to acquaint himself with all the special and crude methods of the ancients before becoming familiar with the more powerful modern methods. The history of our subject is useful to the teacher provided he uses it to suggest methods rather than to supply these methods.

One of the most important questionable points in a general history of mathematics is the emphasis, or the lack of emphasis, on mathematical insight into the questions under consideration. It is evident that statements which have no mathematical sense such as the following: "In 1869 C. F. Geiser showed that 'the projection of a cubic surface from a point upon it on a plane of projection parallel to the tangent plane at that point, is a quartic curve; and that every quartic curve can be generated in this way," which is found on page 318 of the history noted above, should be avoided as far as possible. Similarly, authors should aim to avoid statements which are apt to be misunderstood because additional data must be supplied before they have any real significance, such as the following: "Newton uses his formulas for fixing an upper limit of real roots; the sum of any even power of all the roots must exceed the same even power of any one of the roots," which is found on page 202 of the same work.

There are, however, many statements which are perfectly accurate and yet fail to bring out the real mathematical situation. As regards modern developments some such statements can scarcely be avoided in view of the fact that details would involve an almost endless amount of explanations, but such details can be more easily supplied as regards ancient mathematics. For instance, the following theorem relating to the addition of the digits of a positive integer is found in various general histories of our subject. If any three consecutive positive integers, of which the largest is divisible by 3, are added together there results a number which is either 6 or reduces to 6 by the successive addition of its digits. The full significance of this theorem becomes clear only after considering it as a special case of the theorem that numbers which are congruent modulo 9 constitute an invariant with regard to the operation of adding digits, and observing the connection between this theorem and the ancient rules relating to "casting out the 9's."

We shall direct attention here to only one more questionable historical statement which appears on page 175 of the history to which we referred several times above, and reads as follows: "The new feature introduced by Descartes was the use of *an equation with more than one unknown*, so that (in case of two unknowns) for any value of one unknown (abscissa), the length of the other (ordinate) could be computed." From the words in italics one would naturally infer that

the emphasis was to be placed on the fact that Descartes used equations involving more than one unknown. On the contrary, the emphasis should be placed on the functional relation between the unknowns.

Equations with more than one unknown are very old in mathematics. In fact, it is well known that statements equivalent to such equations appear on one of the oldest fragments of papyri. In modern notation these equations have been expressed as follows:

$$x^2+y^2=100 \qquad y=\tfrac{3}{4}x.$$

A considerable part of the well known "Arithmetica" by Diophantus relates to equations in two unknowns and the Hindus used equations with more than one unknown, distinguishing them by colors, as the black, blue, yellow, red, or green unknown. As regards the expression of functional relations Descartes' work is well known to have been epoch-making.

In the present state of our knowledge of the history of mathematics it seems almost impossible to avoid questionable statements in works which aim to cover the entire field. The suggestions here offered relating to the other side of questions involved in various such statements may serve to arouse interest in a few important historical matters, especially on the part of those who enjoy the clash of views in a friendly combat.

THE EARLIEST PRINTED ILLUSTRATIONS OF NATURAL HISTORY

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IN 1475, soon after the completion of the first quarter-century of printing, there appeared in Augsburg a popular book on natural history illustrated by woodcuts of animals and plants, some of which bear internal evidence of having been drawn from nature and of having been especially prepared for this book. Under the archaic title "Das Puch der Nature" by Conrad von Megenberg we have the prototype of illustrated treatises on natural history and popular medicine. It stands alone and is not genetically connected with any other; nevertheless it was the first of its kind, and perhaps it served as a model for other illustrated books of similar purpose which were published in Germany within the next ten or fifteen years. Conrad's book of nature passed through six editions before the year 1500 and enjoyed a wide circulation; we might even speak of it as one of the best sellers of the period, and thus the venture of the enterprising publisher, Hans Bämler, justified itself.

Since the book was the first to contain printed pictures of animals and plants it is of especial interest and challenges examination, not alone for philological study of the old dialect (Bavarian-Austrian) in which it is printed, but more especially as representing the scientific aspect of the period.

Another book, the "Gart der Gesuntheit" ("Herbarius zu Teutsch," etc.), published in Mainz in 1485, surpasses all others in the quality of its illustrations even up to the herbal of Brunfels published in 1530. This statement is so much at variance with the commonly expressed opinion of well-known writers of biological history (Sachs, Greene, Miall and others) that it seems desirable to reexamine the originals of each of these books from the standpoint of content and quality of illustrations. Both books are very rare and have been accessible to few naturalists. One bibliographer, Dr. Jos. Frank Payne, has (1902) discerned the unique position occupied by the Gart, "the publication of which (he says) forms an important landmark in the history of botanical illustration, and marks perhaps the greatest single step ever made in that art. It was not only unsurpassed but unequaled for nearly half a century." Dr. Payne does not comment on the few pictures of animals in the "Gart der Gesuntheit" but they are equally notable.

The book of nature and the "Gart" (for this title see below) have not received the notice of which they are deserving partly because attention has been diverted from them by the notice given to the Hortus Sanitatis which was published in 1491 and in many editions thereafter. The "Hortus Sanitatis" belongs to the same family of publications as the "Gart der Gesuntheit," but on account of its size, its numerous illustrations (1066), its later date of publication and its great popularity, it has been natural to assume that the "Hortus Sanitatis" represented the highest development of this class of books, and as a consequence, the two earlier (and much rarer) books have been passed by lightly and much greater attention given to the "Hortus Sanitatis."

The book of nature (1475) and the "Gart" (1485) not only antedate the Hortus Sanitatis but they are superior to it in several particulars; as already mentioned this superiority is especially marked in the better class of illustrations of the "Gart." These two early printed books represent a forward trend of the human spirit and should come under separate consideration. If ever we are able to gage the thought-life of the later Middle Ages, and especially of that interesting period of intellectual development just preceding the full bloom of the Renaissance, it must be accomplished by a study of the publications of the period. Accordingly, let no one assume that these books are merely curiosities of antiquarian interest.

The books of the time which have claimed most attention from scholars show another phase of the mental life of the period—that of the mystical-minded scholar and the theologian whose writings were more subjective in type, while Conrad's book, as well as the "Gart," represent the more objective or scientific attitude of mind. These two currents of mental life ran parallel, but at this time the instinct for creation through subjective methods was more conspicuous and the scientific attitude was undeveloped if not primitive.

The literary output of the period was more diversified than one might at first suppose. Besides Bibles, books of devotion, the famous "City of God" of Augustine, other religious writings and also legal treatises, a reader of the period found to hand printed copies of secular writings—some of belles-lettres and others of diversion: Dante, Petrarch, Boccaccio, Chaucer, Aesop's fables, the Bidpai stories showing affinities with the "Arabian Nights," Breidenbach's travels, the "Dialogues of the Creatures," "Reynard the Fox," "Romaunt of the Rose," etc. All these lay outside the field of the scientific and realistic books which were embodied in medical treatises and nature books.

Also dealing with nature (as well as other subjects) were such writings as the huge encyclopedias of Vincent of Beauvais, the "Properties of Things" by Bartholomæus Anglicus and the "Liber de naturis rerum" of Thomas of Cantimpré (the latter being the original of

Conrad's book of nature). Furthermore, it should be remembered that the printing presses were turning out on a relatively large scale the remains of classical and early mediaeval learning. Among these may be mentioned the scientific writings of Aristotle, Theophrastus, Pliny, Dioscorides and Galen.

But the book publishers of the period were desirous to stimulate a wide market for the sale of their wares and did not depend wholly on curiosity and mental interest. In the Latin preface of the "Hortus Sanitatis," published in 1491, there is a clever appeal to the commercial instinct. The writer, or compiler, says that he has been moved first and foremost by compassion for the poverty of those sufferers who have not the means to hire doctors and apothecaries and that by the teachings of the book these persons "with quite small expense to themselves will be able to compound helpful remedies and perfect medicines." This gives it the character of a book on popular medicine intended for the people. Another feature had more influence on the thought of the time; by pictures and descriptions, the attention of the people was directed to the productions of nature and information was spread regarding animals, plants and minerals. As Klebs says, "almost the entire structure of modern (biological) science rests on such humble beginnings." These books gathered what the monastic student had "milked," often uncritically, from the brain of the ancients and added comments and observations of their own. These additions mark the onset of inductive science. On the whole, the "Book of Nature," the "Gart" and other similar books represent a phase of the struggle to get away from the mystical and the subjective and to arrive at independent observation of nature. This was the call of the human spirit to engage in objective studies to which some types of mind are temperamentally inclined.

Conrad von Megenberg's "Puch der Nature"

This nature book was a German translation, with some changes, from the Latin "De Naturis Rerum" of Thomas of Cantimpré. The original was completed by Thomas about 1248, and translated by "Cunrat von Megenberg" a hundred years later. It was a complete review of nature and the first book of its kind of the Middle Ages. The German translation existed in manuscript for 125 years before it was first printed in 1475. That it was popular and widely circulated in manuscript form is attested by the numerous manuscripts in existence. Pfeiffer mentions 17 copies of the German translation in the library at Munich, 18 are reported from Vienna and many copies are known in other continental libraries.

In its printed form the book is now very rare. There are two copies of the first (1475) edition in the United States, both in the J. Pierpont Morgan library at New York. Through the courtesy of Mr. Morgan and

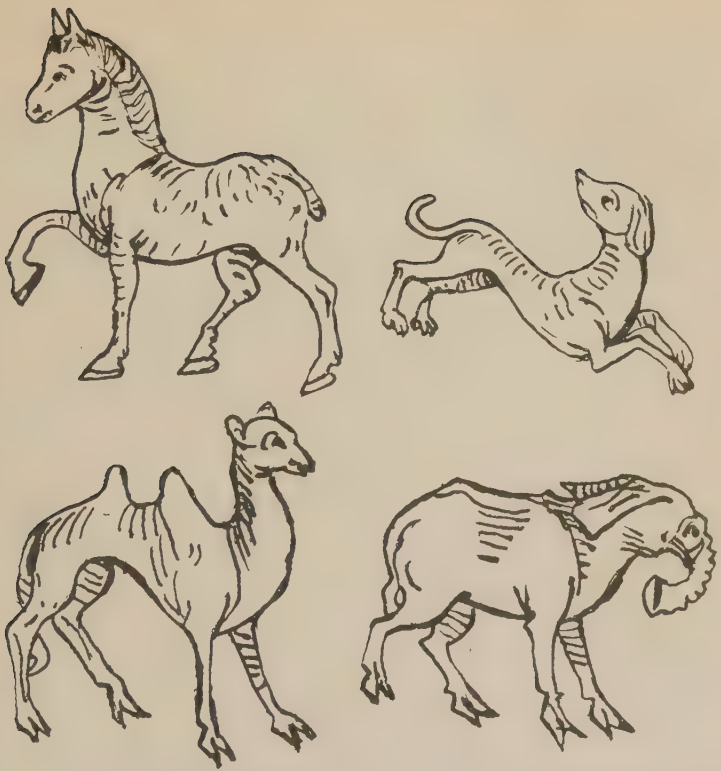

FIG. 1. TRACING OF FOUR FIGURES FROM A FOLIO PLATE OF TWELVE QUADRUPEDS. PUCH DER NATURE (1475). ORIGINAL IN THE J. PIERPONT MORGAN LIBRARY

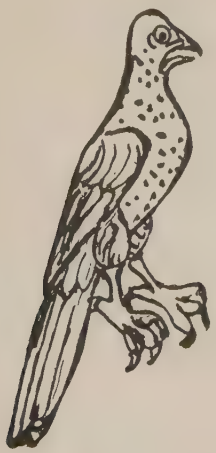

FIG. 2. TRACING OF THE FALCON FROM A PLATE OF THIRTEEN BIRDS. PUCH DER NATURE (1475). ORIGINAL IN THE J. PIERPONT MORGAN LIBRARY

FIG. 3. PHOTOGRAPH OF A FOLIO PLATE OF INVERTEBRATES. PUCH DER NATURE (1475). ORIGINAL IN THE J. PIERPONT MORGAN LIBRARY

his librarian I have had the opportunity of examining these books and taking photographs of the plates.

The short foreword, which was probably inserted by the publisher, telling the scope and the source of the book is as follows:

> Here follows the book of nature which treats first of the peculiarities and nature of man, then of the nature and the properties of the heavens, of beasts, of birds, of plants, of stones and of many other natural things. And upon this book a highly learned man worked for fifteen years collecting for his use from the following named sacred and secular teachers, poets and other approved doctors of medicine, such as Augustine, Ambrosius, Aristotle, Basil, Isadore, Pliny, Galen, Avicenna, etc., and many other masters and teachers. Out of these and others he read, made excerpts and compiled the book. Which book Master Conrad von Megenberg transferred from Latin into German and wrote it out. Here is a useful and entertaining material from which every man can learn many unusual things.

Among the several other authorities cited in the book, but not mentioned in the preface, is the "Physiologus."

In its original form, therefore, it purported to be merely a compilation and not a book of original studies. After fifteen years of labor Thomas of Cantimpré had completed the "De naturis rerum" and Conrad merely translated it. The German translation was repeatedly printed and widely distributed, while the original remains unpublished to this day. A curious turn of fate, as remarked by Sudhoff who says further, that the original Thomas, "in spite of all its faults and errors, had always served as an important document of medieval science and deserved publication certainly more than many another work."

Conrad's translation was not made directly from the text of Thomas, but, as Haupt has shown, from a working over and rearrangement of Thomas by Bishop Albert of Regensburg.

Conrad, the translator, was a cleric and teacher, who after various vicissitudes of life, became Canon at Regensburg. Evidently he was a lover of nature and had written a book on the world (Sphæra) and another on the "Gestelt der Welt." In translating the book of nature he says he rearranged and added to the book as well as omitted some points. Indeed, some of the manuscripts of Thomas contain an account of 193 animals not found in the translation (Carus), but there still remain 267 animals commented upon. He seems to have improved and added to the plants (Meyer). From time to time, he makes original comments, either expressing doubt of some statement or adding a remark of his own—introducing what he has to say by "I also Megenberger says"—but these comments are not of weighty importance.

Evidently the manuscript used by Conrad did not contain the author's name since he expresses doubt as to the writer of the Latin book, "whether Albertus Magnus or not, I do not know." The source of the book, however, is now well established.

FIG. 4. PHOTOGRAPH OF ONE OF THE TWO BOTANICAL PLATES. PUCH DER NATURE (1475). ORIGINAL IN THE J. PIERPONT MORGAN LIBRARY

A complete copy of Conrad's book should contain 292 folio leaves and twelve plates of woodcuts. The two copies of 1475 which I have seen in the J. Pierpont Morgan library are rather handsome volumes as to format and printing. They were derived from the library of William Morris. Each copy contains the twelve folio plates and is nearly complete as to text. This is somewhat notable, since Hugh William Davis says that five of the plates are missing in the copy of the first edition in the British Museum. All cuts of both books in Mr. Morgan's library are colored alike in detail; accordingly, I presume that they were both done by the same hand or that there was a conventional type of coloring prevailing at that time.

The descriptive part of the book is disappointing. The art of description rests on good observation and at this period independent observation had not been developed. The text is chiefly a series of brief quotations from the writers of classical antiquity and the Middle Ages—Avicenna and Averroës (1198) being among the most recent. The excerpts are mainly folk stories and trivial observations about animal behavior. The book is comprehensive in range but the largest part of it is devoted to animals. In relatively brief compass, the text preserves for us the medieval lore about animals, plants and stones, but it is not descriptive science. I have not found a systematic or methodical description of any animal, but only quotations beginning "Aristotle says, Pliny says," etc. A few authors are cited under each title. Habits and behavior are spoken of but there is no description of appearance, color form, etc. Among flowers, rarely is the color of the flower mentioned (as frequently it is in the "Gart"). The comments on particular objects vary in length from seven lines up to two or three pages. Frequently one account occupies from one quarter to one half a page.

The general tone of the writing is shown by the following slightly abbreviated quotation about the lion. This is one of the longer (but by no means the longest) accounts and answers for the others.

The Lion is king of all other animals, as Jacobus and Solinus say. This beast has nothing false, untrue or cunning about him. He is so hot by nature, that one may think he is always in a fever. The lioness always at first gives birth to five whelps,then to four, then to three, thereafter to two and the fifth time to one only. After that she is barren. Augustine says, when the cubs are born, they sleep three days until the father comes; he cries very loud over them, and being frightened by the noise they awaken. The lion fears the sharp sting of the scorpion and flees from it as from a deadly enemy. He fears also the rattling of wheels as they turn on the wagon, but he fears fire the most. Solinus says, that the lion is not easily angered, but being enraged, he seeks the offender (Zornmacher) and tears him to pieces. He never attacks man willingly, and only in great hunger. Adelius says, when the lion sleeps, he has his eyes open. When he travels, he blots out his footsteps with his tail, so that the hunter may not find him. Also Pliny says, that lions are friendly among themselves and do not fight. Aristotle says,

FIG. 5. PHOTOGRAPH OF A FOLIO PLATE OF ANIMAL FIGURES. BREIDENBACH'S TRAVELS (1486). ORIGINAL IN THE J. PIERPONT MORGAN LIBRARY

the lion hides his bone the same as the dog. When in hunger, he draws with his tail a large circle on the ground and roars loud and frightens other beasts so they do not dare to come within the circle. He scorns the eating of yesterday and the remains of his former feasting. Some say that the lion dies of his own anger, he is so violent. The lion willingly captures the wild ass and chases him in nature. Ambrose says, when he is sick, if he catches an ape and eats him, he becomes well. When the lion drinks dog's blood, he becomes well. Solinus and Pliny say, that when the lion holds his tail quiet, he is mild and friendly; but that is seldom. . . . . Pliny says, that lion's flesh and especially the heart is good for people to eat; those who are too cold by nature, when they eat lion's flesh, will become warm. The lion's bones are so hard, that one can strike fire with them as with a flint. The lion's fat is an antidote against poison. When a man annoints himself with wine and lion's fat, it drives away all beasts from him, also snakes. The lion's fat is of warmer nature than that of any other animal. The lion is continually afflicted with a quartan fever so that he desires especially the flesh of apes, that he may become well. Lion's fat with oil of roses frees man's face from freckels, clears it and keeps it so. The lion's neck is thick and the flesh of the neck is cartilaginous, so he can not raise his head backwards. Alexander says, that the lion has great strength in his breast, in his fore feet and in his tail. *Leon* in Greek is a king, therefore is this beast called *leo,* because he is the king of all other beasts. The lion is warmer by nature in the fore part of the body and colder in the hinder part; also the sun is in the constellation of the lion. Aristotle says, that of all animals the lion has no marrow in its bones except in the femur. Therefore his bones are harder than those of any other animal, except the dolphin. The lion's intestine is like the dog's intestine. The lion is feverish in the summer, but is well in the winter. He also becomes feverish before the face of man.[1]

The duck is dismissed with seven lines, while the account of the hen is unusually long, occupying three and one-half pages. Regarding the ass, "Pliny says, it has white milk . . . that Nero was nourished on ass's milk."

Each of the twelve parts into which the book is divided is preceded by a general introduction in which one often finds moralizations and expression of theological views. In various places Conrad makes uncomplimentary allusions to the profligate priests (üppigen Pfaffen), who like the ass are weak when they should carry the cross and strong when they are unchaste. The bishop is compared to the peacock and also to the raven. It is merely a conjecture, but the great rarity of the book may be partly owing to these attacks on the priests. These allusions would naturally arouse the hostility of the very powerful theological bodies and, not unlikely, lead to attempts to suppress the book. In looking over the Index Librorum Prohibitorum, however, I have not found the "Book of Nature" on the prohibited list.

The illustrations in Conrad's book of nature are on twelve folio

[1] I am indebted to my colleague, Professor James T. Hatfield, for assistance in translating some of the more obscure passages.

De reptilibus multis dyalogus cente[illegible]nus vicesimus ·:·

Reptilia multa se sup humū simul solaciabantur ad so= lem sed basiliscus id est serpens venenosus ut supra dictum est in dyalogo quadragesimoprimo in mediū exiliuit clamans ·quis in duello mecum salire poptat veniat et pugnabo cū eo Testudo autem in medio processit cum ipsa pugnatura Dum autem simul pugnarent basiliscus cupie= bat eam mordere et toxicare ·sed testudo trahebat et caput et pedes in concham & non poterat eam tangere Postea ve= ro extrahebat et basiliscum cum dentibus et ungulis acutea= bat·sic enim victus anguis erubuit Paululum post denuo se fortificauit ·et volens se excusare & erat turpiter victus ait · volo me vindicare · si est inter vos aliquis preliator ve=

FIG. 6. ANIMAL FIGURES IN THE DIALOGUS CREATURARUM (1480). ORIGINAL IN THE J. PIERPONT MORGAN LIBRARY

plates, inserted as leaves separate from the text, one plate at the beginning of each division of the book. The wood-cutting is coarse, and the drawings are by no means so good as those of the "Gart." So far as known these sketches have no forerunners; they are not traditional figures copied from earlier manuscripts, as was frequently the case of illustrations printed before 1530. On ten of the twelve plates there are not less than eighty-six figures of animals (some of the smaller repetitions not being counted). The remaining two plates contain nineteen figures of plants and trees.

The illustrations vary in quality—when the figures are of domestic animals, so that the designer could see examples, the figures are rather good—see the dog and the horse in Fig. 1. The goose, dear to the heart of the German for festive occasions, the falcon (Fig. 2), the woodpecker, the peacock, although crude are evidently drawn from nature. The exotic animals, however such as the camel, the lion, and especially the elephant (Fig. 1), with cleft-hoof and schematic trunk, are very bad—the designer had no specimens to look at. The fishes are not well drawn. The general appearance of the plates with a rough border is shown in Figs. 3 and 4. The plate of animals (Fig. 3), shows several insects—ants, bees, grasshoppers, butterfly,—a spider, a snail, etc. The plate of plants (Fig. 4), shows the grape vine, the apple tree, the pear tree, and other pictures less easily recognizable.

The figures in the "Book of Nature" are the earliest printed pictures of natural history—they mark the beginning of scientific iconography. Arnold Klebs, in his Incunabula Lists (1917), speaking of the "Herbarium" of Apuleius Barbarus, Rome, 1483 (and 1484), says: "Its illustrations, crude formalized pictures of plants, are, with possibly one exception, the earliest ones in a printed book." He does not mention the "Book of Nature," but certainly there were two plates of botanical illustrations in this book published in 1475. The rarity of Conrad's book, and especially of perfect copies, accounts for the little notice it has received and also for misconceptions regarding the number of plates which it contains. Mrs. Arber in her very fully illustrated treatise on herbals reproduces one of the plates from the "Puch der Nature" (1475), and speaks of it as "the single plant figure" with which the book is illustrated. Hugh William Davis, in "Early German Books" has already pointed out that five plates are missing from the copy of the first edition in the British Museum. For the second plate of botanical figures see Fig. 4.

The introduction of pictures into printed books of science was an important step. The preparation of cuts forced observation and sharpened it. Through this means attention was directed to details and observation was promoted. This was an entering wedge of independent observation at a time when observation was struggling for the right to exist. The preparation of the figures required greater accuracy

FIG. 7. PHOTOGRAPH OF A FOLIO PLATE OF ANIMALS. BARTHOLOMAEUS ANGLICUS (1486). ORIGINAL IN THE J. PIERPONT MORGAN LIBRARY

and some independent observation and these original efforts were allowed to stand. They did not provoke the hostility of the censors as did original comments. The pictures might pass, but expressions of independent opinion might be contrary to theological doctrine. The pictures of the "Gart der Gesuntheit" were so much more notable that further comment will be withheld until the next section.

It will be interesting for local color to compare figures of animals in contemporary books of different purpose. In connection with the special examination of the "Book of Nature," I also had for use in the J. Pierpont Morgan Library copies with illustrations of Breidenbach's "Travels" (1486); several copies of Bidpai (1486 and others); the "Dialogus Creaturarum" (1480 and others); Bartholomæus Anglicus, in Flemish (1486), and in English (1495); the former with good pictures of animals and plants, the latter with wretched ones.

The single plate of animal pictures in Breidenbach's "Travels" (Fig. 5) contains pictures that are superior as to drawing and as to woodcutting. Although there are some mythical animals represented, the camel and the giraffe are well executed and are evidently drawn from nature. William Morris says, in general, of many pictures in Breidenbach's book: "These woodcuts are remarkable, not only as the best executed illustrations in any medieval book, but as being the first woodcuts in which shading is used in masses and not merely to help the outline." In Bidpai ("Buch der Weisheit" and other titles) is a grotesque figure of an elephant with cleft hoofs and a long bovine tail and also a schematic trunk similar to the one in Conrad's picture (Fig. 1). In the "Dialogus Creaturarum" (1480), there occurs an elephant with the soliped hoof of the horse and with the horse's tail (Fig. 6). Now these are not pictures drawn for a scientific book but as representing the conception of these animals by designers of the time they are significant. The figures in the Flemish edition of Bartholomæus Anglicus (erroneously de Glanville), (Fig. 7), although published in 1486, far surpass those of the English translation, published in 1495, by Wynkyn De Worde. The plate of quadrupeds (Fig. 7), of birds and of plants of the Flemish edition show signs of observation from nature (note especially the elephant in Fig. 7). The figures in the English edition on the other hand are wretched caracitures—some of them being degraded copies of the figures of Conrad's book. Mrs. Arber published the plate of plants from the English edition of 1495, but the botanical plates in the earlier Flemish edition are much superior.

For readers who may be interested in looking over the literature relating to the "Book of Nature" and its translator, I make note of the chief references consulted. Besides the original edition of 1475, I have made use of the analyses of the book by Choulant ("Anfänge wissenschaftlicher Naturgeschichte und naturhistorischer Abbildung in

Acorus geel lilien
Corus vel ſpatella latine·Glaſpatella vel
nerea vel pyperapiũ grece·Arabice vero
Maeg vel bogog vel zweg

FIG. 8. PHOTOGRAPH OF THE YELLOW FLAG. GART DER GESUNTHEIT (1485). ORIGINAL IN THE SURGEON GENERAL'S LIBRARY

christlichen Abendlande," 1856); by Meyer ("Geschichte der Botanik," 1857); by Sudhoff ("Studien zur Geschichte der Medizin," 1908) and the bibliographical notice by Hugh William Davis in "Early German Books" in the library of G. Fairfax Murray, 1913. In 1861, Pfeiffer published (without illustrations) the entire book under the title "Das Buch der Natur, von Konrad von Megenberg, Die erste Naturgeschichte in Deutcher Sprache." This is a study of the book from the philological standpoint and is accompanied by a dictionary of some 250 pages. There is also a metrical translation in Flemish, and in rimed verse, entitled "Naturen Blœme." This was made by Jacob de Mærlandt who died in 1300, so that his translation preceded that of Conrad. The first part of the Naturen Blœme was published in 1856 and the complete work in 1878.

The "Gart Der Gesuntheit"

While the "Book of Nature" had a long history in manuscript, the German translation going back to 1349, the Gart, on the other hand, although a compilation, seems to have been a product of the time—arising about the printing house. It was thus an expression of publisher's enterprise—the excerpts being chiefly made by a physician who acted as the scientific collaborator, and the blocks being cut under the eye of the publisher. No anticipations of the illustrations nor of the text are known, except that the text is pieced together out of earlier writings on nature. From the account in the preface it would appear to have been the product of the combined labors of the original designer, a master of medicine and a skilful artist. The following quotation is taken from Mrs. Arber's translation of the preface:

> Since, then man can have no greater nor nobler treasure on earth than bodily health, I came to the conclusion that I could not perform any more honorable, useful or holy work or labor than to compile a book in which should be contained the virtue and nature of many herbs, and other created things, together with their true colors and form, for the help of all the world and the common good. Thereupon I caused this praiseworthy work to be begun by a Master learned in physic, who, at my request, gathered into a book the virtue and nature of many herbs out of the acknowledged masters of physic. . . . . But when, in the process of the work, I turned to the drawing and depicting of the herbs, I marked that there are many precious herbs which do not grow here in these German lands, so that I could not draw them with their true colors and form, except from hearsay. Therefore I left unfinished the work which I had begun, and laid aside my pen, until such time as I had received grace and dispensation to visit the Holy Sepulchre, and also Mount Sinai. . . . . Then, in order that the noble work I had begun and left incomplete should not come to nought, and also that my journey should benefit not my soul alone, but the whole world, I took with me a painter ready of wit, and cunning and subtle of hand. And so we journeyed from Germany. . . . . In wandering through these kingdoms and lands, I diligently sought after the herbs there, and had them depicted and drawn with their true color and form. And after I had by

FIG. 9. PHOTOGRAPH OF THE WHITE LILY. GART DER GESUNTHEIT (1485). ORIGINAL IN THE SURGEON GENERAL'S LIBRARY

God's grace, returned to Germany and home, the great love which I bore this work impelled me to finish it, and now, with the help of God, it is accomplished. And this book is called in Latin, *Ortus Sanitatis,* and in German, *gart d'gesuntheyt.*

Considerable confusion has arisen as to the distinctive title by which this work should be known. Choulant, who in 1857, gave the first complete analysis of the book, called it the "smaller Hortus" and thus it came to be confused with the "larger," or true "Hortus Sanitatis" which was first published in Mainz in 1491, and became widely distributed in later editions. Although the "Hortus Sanitatis" owes something to the "Gart" as a forerunner of the same type, it differs in language and in extent—being much more voluminous and having 1066 figures, while the "Gart" originally had a total of 397 illustrations. Most of the pictures of the "Gart" were copied and recut for the "Hortus Sanitatis," but they were degraded and of much lower quality. The "Gart" was originally prepared in German; "the Hortus Sanitatis" was in Latin, but not a translation of the "Gart" although modeled after it and showing generic resemblances to it. Neither was the "Gart" a German translation of the Latin "Herbarius" which preceded it by one year (1484). The text and, notably, the illustrations are different, not only more numerous (150 in the Herbarius and 397 in the "Gart") but of superior quality.

The extant copies are rarely complete and the title page is frequently missing; but, whatever the title on the fly leaf of the various issues and variants of the "Gart"—"Herbarius zu Teutsch," "Ortus," etc., there occurs an unvarying title in every preface—"And this book is called in Latin Ortus Sanitatis, in German ein Gart der Gesuntheit." (From the first Mainz edition, 1485). Arnold Klebs in his Incunabula Lists (1917) has greatly clarified the matter by a complete analysis of what he calls the Hortus family, showing the family to consist of some forty issues of related books—the "Hortus Sanitatis" of 1491 being the central member and the most extensive. The original edition of the "Gart" is the most important for determining the quality of its illustrations and any confusion of title should by all means be avoided. The suggestion of both Sudhoff and Klebs to designate the work by the short title "Gart" is opportune since this gives a distinctive title that can not be confused with that of any other member of the "Hortus" family. The "Gart" is the original of the entire "Hortus" family. The name of the designer of the book is not known but the scientific collaborator is believed to have been Johann de Cube (mentioned on page 127 near the end of chapter 76) and identified by Sudhoff with Johann de Wonnecké, a practicing physician of Frankfurt at the end of the fifteenth century.

A complete copy of the "Gart" of 1485 should contain 356 folio

Vulpis eyn fuſch Cap·rrrrxxvj·
Vlpis latine·¶ Die meiſter ſprechen das diß gar ein wedru
glich dier ſy wan die hunde es tagen ſo nympt es den ſwantz

FIG. 10. PHOTOGRAPH OF THE FOX. GART DER GESUNTHEIT (1485). ORIGINAL IN THE SURGEON GENERAL'S LIBRARY

leaves, 435 numbered chapters with 386 pictures of plants (one repeated) and eleven of animals (one repeated). The copy placed at my disposal at the Surgeon General's Library in Washington has 320 leaves, and 427 chapters but lacks a few intervening leaves. I am greatly indebted to Colonel Garrison and others of the library staff for assistance and opportunity to photograph the plates of the book. Choulant mentions thirteen issues of the "Gart." The number of illustrations varies in the different issues—one edition, with the addition of genre-pictures, has as many as 542 pictures (Klebs). Choulant says that the pictures of the pirated edition, printed in Augsburg five months after the Mainz edition and attributed to the press of Anton Sorg, are for the most part better than those of the original edition. I have been much puzzled by this statement of Choulant as to the quality of the pictures, and, owing to the recognized thoroughness of Choulant's work, am reluctant to question it. However, the book to which Choulant refers (Hain 8949*) is assigned by recent bibliographical experts to the press of Schönsperger. I have recently seen a perfect copy of this in the Newberry Library of Chicago, which is not listed in the Census of Fifteenth Century Books owned in America. It is dated at Augsburg, August 22, 1485, but the name of the printer is not given. As determined by reference to Haebler's *Typenrepertorium*, the book is printed in Schönsperger type, No. 1, and is 120 as to size. There remains the question of the quality of the illustrations—those in the book of the Newberry Library are smaller and inferior to those of the original Mainz edition. I have also seen the Augsburg edition of March, 1486, from the Schönsperger press, derived from the collection of the late Theodore L. De Vinne, and now owned by the John Crerar Library of Chicago. This is a smaller book, printed in two columns instead of full-page, and its illustrations are much smaller and much inferior to those of either the Mainz or the Augsburg edition of 1485.

It is in reference to the illustrations that the "Gart" is especially notable. The pictures are chiefly those of plants, numbering 386, while there are only eleven pictures of animals. The pictures vary in quality, but seven pictures of animals and five or six of plants are of unique perfection among the early printed illustrations. The picture of the yellow flag (Acorus) (Fig. 8), of the white lily (Fig. 9) and of the fox (Fig. 10) are fine examples of drawings from nature. The cut of the yellow flag has been published full-size by Dr. Payne and by Mrs. Arber, but, so far as I am aware, the figures of the white lily, and of the fox and other animals have not been reproduced.

No one can examine the original cuts and retain any doubt that they were drawn from nature by a skilful artist and a careful observer. The lines of the woodcuts are coarse but the few best sketches rival

those published by Brunfels (1530) and Fuchs (1542). The best figures in the "Gart" show the highest level to which botanical and zoological illustrations attained not only in the fifteenth century but also in the first third of the sixteenth. Fifty-five years before the renovation of botanical illustration by Brunfels, and sixty-seven years before the publication of the figures of Fuchs, the best pictures of the "Gart" stand out as beacon lights in the development of scientific illustration. They are of singular importance in the history of scientific iconography and are deserving of great praise. An unpredjudiced examination of them can not fail to modify the incorrect estimate as to the quality of all printed illustrations of natural history before those of Brunfels.

In the botanical books that followed for fifty-five years from the printing presses of various countries, the pictures of the "Gart" were copied and recopied, but in the process they were degraded and conventionalized, so that one can get a correct impression as to quality only by examining those of the first Mainz edition. Even so careful and original a student as E. L. Greene, whose "Landmarks of Botanical History" shows great thoroughness, maturity of judgment and first-hand acquaintance with the sources, repeats the generally accepted opinion, saying (p. 195): "To a generation that had been accustomed to such books as the 'Hortus Sanitatis,' filled with the most wretched caricatures of plants in place of true representations of them, this great book of Fuchsius must have appeared as nothing less than luxurious" and again, (p. 167): "Even 40 or 50 years before these fathers of plant iconography there were printed copies of the 'Hortus Sanitatis,' and its German version 'Gart der Gesuntheit' illustrated by some 500 wood engravings of plants. Doubtless the wretched character of these first printed plant pictures, along with the great popularity of the books containing them, were what moved Brunfels to undertake the publication of the 'Herbarium Vivæ Icones.'" Here a direct reference is made to the "Gart der Gesuntheit" (the "Hortus Sanitatis" having 1066 figures, instead of 500). The criticism will apply to the degraded pictures of the "Hortus Sanitatis" but not to the better pictures of the "Gart." The explanation of such an unwarranted sweeping conclusion is doubtless to be set down to the great rarity of the "Gart," and to the belief that, since the "Gart" was an earlier publication of the same type, the pictures of the "Hortus Sanitatis" can be taken as showing the quality of the pictures of the earlier book.

No one can look at the pictures of the dodder, the yellow flag, the white lily, the fox, etc., and consider them as wretched caricatures: they rival the printed pictures in the herbals of Brunfels and of Fuchs as to quality and fidelity to nature.

GETTING MARRIED ON FIRST MESA, ARIZONA

By Dr. ELSIE CLEWS PARSONS

THERE are three towns or rather two towns and a suburb on First, or East Mesa, Walpi, the Hopi town, with its suburb Sichumovi, and Hano or Tewa, a Tanoan settlement from the East, made, it is said, two hundred or more years ago.

It was from Yellow-pine, a young Tewa woman married for about three years that I heard most about Tewa wedding practices. Yellow-pine spoke English comparatively well, well enough to tell a story in English in about the same way as she would tell it in Tewa. This is her narrative:

"The boy goes to the girl's house at night to see her. If the girl's mother does not want him, she tells the girl. If she wants him, she says, 'You can talk[1] to him,' she says. (But if the girl wants the boy, even if her people do not want him, she can talk to him.) The boy tells his people; if they say yes, then the boy comes again and tells the girl. Then the girl makes *piki* [wafer bread, in Tewa, *mowa*], the narrow kind of *piki,* like sticks (*makana*). She makes *piki* all day. She piles it high, beginning early in the morning. At night the girl and her mother take the *piki* to the boy's house. The boy's people are happy and say, 'Thank you,' and give them meat. They bring it home. From that they all know that he is going to marry her. Now, any night, they take *piki* again to the boy's house, and the boy's people give meat. From then on they begin to get married. . . .

They grind corn every day until they fill ten or twelve boilers [store-bought tin boilers]. It takes a month to complete that work. They also prepare white corn to put in water for the boys to drink. Then they are ready. They go to the boy's house to tell the boy's people they will come in four days. The boy's people get things ready to eat. The girl tells her uncles [maternal uncles or kinsmen] and fathers [paternal kinsmen] to come to her house on the night they plan for. . . .

On this night they dress the girl in her *manta* [i. e. ceremonial blanket] and wheel her hair. Then they go to the boy's house where all the boy's people are gathered together, and where they have set out meat and bread and coffee. 'We have brought this girl to you to grind as much as she can,' say the girl's uncles. 'Is that so? All right. We are glad to have her,' they say. . . .

Next day, early in the morning, the girl starts to grind. She has to grind all day,[2] stopping only to eat. For three days the girl grinds. Early in

[1] At Zuñi, the New Mexico pueblo where custom is most like Hopi custom, "to talk to" is also the usual expression for courting.

[2] I. e., until about 4 p. m., the closing time of the Hopi work day.

the morning of the fourth day they wash the girl's head. The girl grinds once more and finishes. They [in the girl's house] make many bowls of blue corn meal, and they make *mowasi* (corn boiled and wrapped in corn husk). The girl's clanswomen come in to help. That night the girl's people take to the girl's house five or six boilers [empty] from which they are to give out meal to the boy's people, his aunts [father's sisters], uncles, and mothers [mother's sisters or kinswomen], meal and *piki* and on top *mowasi*. Whatever is left over is given to the boy's mother.

That day the boy's clansmen have brought out cotton to weave into a blanket for the girl. They take the cotton to the girl's house. Her mother thanks them, and puts meal for them in the bowl that held the cotton. The men take the cotton to the kiva to work on it. While they work, the girl has to stay on in the boy's house and do the cooking of the house and the sweeping, while they work for her in the kiva. . . .

When the men in the kiva start to make the white blanket, they take *piki* to them and white corn water to drink. And every day they take bread and meat. At the girl's house they are making heaps of meal and the girl's clanswomen are making *piki*, all night the women are making *piki*, and all night there is a meal set out for them. The next night they make *pigami* (a stew of samp and mutton).

A day or two later they take water to the girl's house and to the boy's house to get ready to make *piki* early in the morning. In both houses they make *piki* to take to the houses of the men who are working in the kiva for the girl. In that way they pay the men for making things for the girl.

Then the boy's mother tells the girl's mother in how many nights they are going to take the girl home again. They get ready, they cook for that night. . . . They put on the girl her blanket and moccasins. That night they cut the girl's hair on the sides.[3] The boy's mother and sisters take the girl to the girl's house. There, to thank them, are assembled the girl's uncles.

Early the next morning, they wash the boy's head [he has followed his wife], all the girl's mothers and father's sisters wash his head.

Four days later they make *piki* all day in the girl's house and towards evening they take it all to the boy's house. . . .

Afterwards, at any time, perhaps two or three years afterwards, the girl has ground in her house ten boilerfuls of corn, including one boilerful of white corn and one of sweet corn. After this grinding, the boy's people go to the girl's house and whitewash the walls and clean house. The next day the boy's mothers and father's sisters bring water to the girl's house. The next day, early in the morning, in the girl's house they start to make *piki*. They make *piki* and they grind meal all day. They fill up the baskets to take them to the boy's mothers. With a pan of beans the girl's mother goes first, the girl in her white blanket follows and the other women. The boy's people are waiting, they get happy. They go to the girl's house and eat. That is all, except that afterwards, at any time when the men who made

[3] Like the hair of Zuñi and Keresan women. Hopi women, married women, part the hair and with a string twist the locks on either side of the face. . . . That the Tewa women have thus preserved their own style of hairdressing is an interesting fact. Style of hairdressing and language are, as far as I know, the only distinctive traits, exclusive of religion or public ceremony, preserved by these Tewa immigrants whose town is within a stone's throw of the houses of their Hopi neighbors.

her things are going to dance, the girl dresses in her white blanket and takes the dancers *pigami*.[4]—It is hard work for us to get married.

A long time ago, it was not so hard. But now we get married just like Hopi, and it is much longer and harder."

It is quite likely, as Yellow-pine suggested, that Tewa marriage ceremonial was formerly more simple, as it is among other Pueblo Indian peoples. In Tewa folk-tales the ceremonial or etiquette of getting married is much the same as in Zuñi tale and practice[5] and probably in ancient Keresan practice.[6] The youth comes to the girl's house. She sets food out for him, he tells the parents what he has come for, they say that it is not for them to say, but for their daughter. (As Yellow-pine remarked, the choice is really with the girl.[7]) The youth leaves, to return another night with his bundle, his gifts of blankets, belt, and moccasins to the girl. If she accepts them, she carries in her turn a gift of corn meal to the young man's house, where she stays four days to grind. There on the fourth morning her head is washed. Then the couple return to live at the house of the girl's mother. A gift of apparel from the man, a gift of meal from the girl, her visit, a betrothal visit, so to speak, to the man's maternal house, the rite of head washing, and the return to the girl's maternal house—this seems to be the generic Pueblo form of wedding to which the Hopi and then the Tewa, in imitation, gave elaboration. Curiously enough, Spanish influence in the Eastern pueblos, Keresan and Tanoan,[8] has tended to a somewhat analogous elaboration, a case of similarity, we can but think, due to convergence.

The extent of the Hopi elaboration appears even more fully in another account of Hopi wedding practices given me by a Tewa man,

[4] At Oraibi, Voth notes that all the brides of the year appear in their white blankets at the close of the *niman kachina* or farewell performance in July, the most elaborate of the masked dances. ("Oraibi Marriage Customs," p. 246. *American Anthropologist.* II. 1900).

[5] Cp. Parsons, E. C. "Notes on Zuñi," pt. II, 302, 307, 322, 325. *Mem. American Anthropological Association,* IV, No. 4, 1917. Lack of weaving at present day Zuñi and the comparatively small amount there of clan cooperation would account in large part for the simpler way of getting married.

Second marriage is among the Hopi comparatively simple because no bridal outfit is to be made.

[6] Dumarest, N. "Notes on Cochiti, New Mexico," pp. 148, 149. *Mem. American Anthropological Association,* VI, No. 3, 1919.

[7] On the other hand I have been told that among old-fashioned people the girl's parents and uncle (mother's brother—note the significance of participation by the uncle to the theory of cross-cousin marriage, p. 265) would look for a boy for her. "My daughter, you will marry that boy," they would say to her. To be sure, "she might leave the boy they chose and choose her own boy," and, if her family were angry, she would go to live with some kinswoman.

[8] Cp. Parsons, E. C. "Further Notes on Isleta," *American Anthropologist,* in proof.

a Bear clansman married into a Hopi (Sichumovi) house and the father of a girl whose wedding was not yet completed, although she was the mother of a three months' old infant. The final gift of meal was not yet made. My Tewa friend had the wedding of his daughter Butterfly in mind, as he talked, I think, although he put his narrative into an impersonal form. Some of his narrative is supplemented by information from his wife, Butterfly's mother.

Whenever a girl finds a boy, the boy comes to see the girl's parents. After he comes, the parents ask what he wants. "I come to see about your daughter," he says. "I don't know about it," says the father of the girl, also the mother of the girl. "We will tell her uncles (*taamatö,* her mother's brothers, etc.), and see what they have to say" . . . The mother of the girl tells her uncles to come to her house. They come at the time she says. (There were six uncles who came in to talk about Butterfly). The mother of the girl says, 'I called you because there is a boy wants our child. I told him I had nothing to say until I called you.' An uncle may say, 'I don't think we want that boy to marry our niece (*tatiwaiya,* sister's child).' Or an uncle may say, 'Well, it is all right.' [In this case] the next time the boy comes, the mother of the girl says, 'I told my uncles. It is all right, they say. Tell your mother and father, and they will tell your uncles, and what your uncles say you tell us.' Then the mother of the boy will call in her uncles and tell them that the boy has been to the girl's house. 'Her mother and father said for me to call you and see what you think about it' . . . If it is all right, the girl's people take some food (*piki*) to the boy's house to let them know that the girl is going to marry the boy. This *piki* the boy's mother distributes to all members of her clan. . . . After this the parents of the boy have to look for buckskin, and for cotton to weave into the wedding blankets (*kwatskyapa*) . . . The girl's people begin to grind corn to fill ten bowls. (To help Butterfly, there were, besides her mother and mother's mother and mother's sister, one other close relative and five clanswomen). Then they say when they will take the girl to the boy's house; they tell the mother of the girl to tell the mother of the boy. The mother of the girl goes and tells the mother of the boy, and she tells all her uncles to come to her house and all her clanswomen (*nahimatö*) and all the aunts (*kyamatö,* father's sisters) of the girl and all the girl's father's brothers (*namatö*) i. e. clansmen. (When our girl married only my own two brothers came, but we asked all the Bear men. We can't tell who will come.)[9] The girl's aunts take some corn meal to the girl's house, in the evening, and the aunt[10] of the girl dresses the girl and puts her hair up in wheels. They all talk to the girl, each of them saying she must work at the boy's house and not be lazy. . . . They go to the boy's house, the girl's aunt goes first, carrying corn meal on her back, then the girl, then the girl's mother and then the girl's father, then the uncles, then the girl's brothers. They all go single file —[the usual Hopi formation for any formal group in progress]. At the boy's house they have prepared supper for all who are to come. They eat supper, they leave the girl there, they go back home. This night the mother of the boy takes care of the girl. Early in the morning the girl gets up to

[9] This is characteristic of all invitations to clanspeople, whether to join in a work party or a name-giving rite or other ceremonial occasion. All are asked; but only the closer relatives feel any obligation to come.

[10] The senior sister or cousin of the girl's father, her aunt *par excellence.*

grind corn. Across the place where the girl is grinding they hang a blanket or, nowadays, a wagon cover, so nobody may talk to her or the sun shine on her. They give her breakfast. . . . The boy's father's mother tells all her clanswomen to go to the boy's house, carrying water. The boy's mother goes around and invites her clanswomen to come to help her against the boy's father's clanswomen. Then they start to fight. (*Möungkipoh mowa,* female connection by marriage; *kipoh,* go to fight). [See p. 265 for explanation]. Then they go back home. . . . The girl grinds all day. The mother of the boy tells the girl when to stop grinding. They eat supper, they go to bed, and the mother of the boy takes care of the girl. . . . The first day the girl grinds white corn, the second and third days, blue corn, the fourth day, pop corn to be drunk in water. On the third day, in the evening, the mother of the girl begins to put up her meal to take to the boy's house. The father or brother of the girl are to take it to the boy's house. All night any of the townswomen may go to the girl's house to help make *piki*[11] as well as the girl's clanswomen, even clanswomen from other towns. . . . Early in the morning they wash the girl's head; first the mother of the boy takes down one wheel of the girl's hair and washes, then the father of the boy takes down the other wheel and washes, then the boy's sisters wash and then his clanswomen.[12] [They wash, as usual, with jucca root suds, dipping the suds on the head with an ear of white corn that is completely kernelled, one of the ears people refer to as "mother" and which is used on many ceremonial occasions. The dipping is quite formal, the head touched lightly four times, when a few words of prayer may be said. A thorough washing follows. After the washing, corn meal is rubbed on face, arms, and body, and meal is given to the person washed to take out and sprinkle, perhaps in a shrine, or on the eastern edge of the mesa, with a prayer for long life and prosperity.] They dress the girl's hair in a roll along each side of the head.[13]

After the head washing they eat the *piki* brought from the girl's house and the *pigami* made in the boy's house and for which his father has killed a cow. Other *piki* is given later in the day to the boy's clanswomen who come in to wash the girl's head, *piki* and on top of it *chaköbiki,* sweet corn meal, which is to be drunk in water.

Then the boy's uncles (*taamatö*) and the boy's father's brothers (*namatö*) [i. e. clansmen] bring in cotton to spin and weave for the girl. The girl's mother who is in the boy's house refills the baskets holding the cotton with

[11] At Oraibi the girl friends of the bride bring in trays of corn meal. The following morning the trays are returned filled with ears of corn by the groom's mother. ("Oraibi Marriage Customs," p. 241).

[12] On Third Mesa at Oraibi the groom's head is also washed at this time, by his mother-in-law. The bodies of the couple are also bathed. The heads of bride and groom are first washed in separate bowls, then in the same bowl, a symbolic act of union, according to Voth, which has lapsed in the case of a bridegroom who has had his hair cut short at school. (Voth, H. R. "Hopi Marriage Rites on the Wedding Morning," pp. 147-9. *Brief Miscellaneous Hopi Papers.* Field Mus. Nat. Hist. Pub. 157. Anthrop. Ser: Vol. XI, No. 2. 1912). At this headwashing rite at Oraibi wrangling by the women (see above and pp. 264-265) is said to occur, the visiting women trying to displace the bride. ("Oraibi Marriage Customs," p. 242).

[13] At Oraibi the girl's hair is taken down from the wheels or whorls worn by virgins by her own mother before mother and daughter take their first gift of meal to the boy's house ("Oraibi Marriage Customs," p. 240). The two rolls of the married woman's hair are wrapped with brown yarn stiffened with grease, so that the hair slips in and out of the wrapping or rather casing.

corn meal, in return for the cotton. The cotton is divided into four piles, the father of the boy is to make one *oba* (white blanket with red and black border), the boy's uncle, an *oba* and an *atö*, (larger white blanket, embroidered), and the boy's father's brother, a belt (*wökukwewa*). [They may also make a dress of black wool]. They take the cotton into the kiva, to spin[14] and weave They don't know how long it will take—several days, sometimes a month, sometimes less. (For Butterfly they were spinning three days, and weaving three days). During this time the girl is grinding or making *piki* in the boy's house, where her clanswomen come to help her. This is for the men at work in the kiva to eat. They take the *piki* to them every afternoon, and sweet corn meal in water. Besides, at this time, the boy's clanspeople come to the boy's house to eat. Whatever corn meal or *piki* is left over is given to the guests to carry away with them, [as is usual in Pueblo Indian circles when a meal is thought of as pay in kind.]

Through with weaving, they make the moccasins, perhaps the boy's father makes them, perhaps his uncle. The night of the day they finish making the moccasins, they take the girl back to her house, first dressing her up in her new things, and the boy follows her. For all of them, the mother of the girl has a meal ready. Earlier in the day the boy's mother has carried the girl's mother a basket of corn. Before the boy leaves his house, his people talk to him, telling him not to be lazy and to be good to everybody in his wife's house—"that is why he is getting married."

Early the next morning [after the night return to the girl's house] the clanswomen of the girl come in to wash the boy's head, just as the girl's head has been washed. Three days later the boy has to get wood. On the fourth day the girl's clanswomen come in to make *piki* all day. That evening they take the *piki* to the boy's house. The following evening those *piki* makers return to the girl's house to which the boy's mother brings some *piki* and meat for them to eat. That is the end of it. . . .

If the girl is married in the fall,[15] the following fall [i. e. a year later] they begin to grind corn again. They put the meal into twelve baskets[16] to take to the boy's house to pay for the wedding outfit."

"When is the first time they sleep together?" I asked. "The night of the morning they wash the girl's head. I forgot that." He forgot that, because, I presume, it was the ceremonial that was of significance, not the personal relationship. "I forgot that"—what more telling comment on wedding ceremonial—anywhere?

On my last visit to First Mesa I had the good luck to witness a wedding attack, the kind of mock or ceremonial attack referred to in the foregoing narrative, by the groom's father's kinswomen on his own kinswomen. High pitched voices were heard out of doors near

[14] Voth got the impression at Oraibi that any townsman might join in the spinning. ("Oraibi Marriage Customs," pp. 243-244).

[15] Fall or winter is the usual season for weddings (Oraibi Marriage Customs," p. 240). None would marry in *Kyamuye*, the dangerous moon, i. e. our December.

[16] The flat gayly colored baskets got in trade from Second Mesa. . . . At the time of my November visit, a year after Butterfly's wedding, her family had acumulated only eight baskets and when I left they had but seven, as they gave me one.

by, about four o'clock of an afternoon, and I was called out to see the sport of the "women's fight" and join in the laughter of the neighbors standing about. There were but two women on either side, to throw water and any refuse they could pick up in the street. One woman had already had her face smeared with mud when I arrived on the scene, and all were drenched. The attackers would vociferate in shrill tones against the closed door of the house of the groom's mother—they were charging the bride with being lazy, unable to cook or to work—and then one of the women would burst out from inside to throw water and to talk back, to say that the bride *could* work, *was* industrious, etc. (No other insults appear to be indulged in on these occasions, there are, for example, no sex jeers.) But for the amused and non-interfering bystanders, two dozen or so, the row seemed thoroughly realistic. It was vigorous, though brief, lasting less than an hour.

The bride of this occasion was the sister of the town chief, the *gigyawuxti* or one of the chiefs of the houses, corresponding to the woman member of the *kyakweamosi* (chiefs of the houses) of Zuñi. She had been married before and separated, as had the groom. During the ceremonial row she remained, not in the maternal house of the groom, but in her own house at Walpi. That morning she had been married by government license in the schoolhouse below the Mesa.[17] Marriage by license in the morning and in the afternoon a wedding assault, what uncritical theorizers would once have called a "rape symbol"! New custom and old, side by side, as is ever the way in Pueblo Indian life

Although the old custom, the assault, is not a symbol of rape, since the grievance is on the part of the groom's people, his father's people against his mother's people, it is, nevertheless, we may fairly assume, give certain other data,[18] a symbol or survival of an earlier custom, that of cross-cousin marriage, where the favored or acceptable marriage was with the father's sister's daughter or clanswoman.

[17] Hopi converts, "Christians" as they are called, are married in the church; but the unconverted are likewise required by government to be married, in the schoolhouse.

[18] See Freire-Marecco, B. "Tewa Kinship Terms from the Pueblo of Hano, Arizona," *American Anthropologist*, XVI, 286, 1914. For his paternal aunt to call a boy "our bridegroom" is also Hopi practice or joke. Another Hopi joke is that were a man to marry his father's sister's daughter (clanswoman), a certain lizard called *manaña* would dart at him. Oppositely, at Laguna, children are told that if they are shy of calling certain connections by the cross-cousin terms of relationship, which is "just like saying husband or wife," the lizard will dart. The cross-cousin terms of relationship in several Pueblo tribes point to some time cross-cousin marriage. In the Hopi *hoinawe*, a war dance, the girl dancers appoint the men dancers, appointing from their mother's brother's sons. As sexual license once characterized war dances, in this choice of dance partners may be seen another hint of cross-cousin mating.

HARMONIZING HORMONES

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THE mechanism of coordination within the animal body is one of the most subtle of all the organ systems of the higher animals, as it is one of the subtlest properties of the microscopic body of the protozoa. What it is in the single cell of the Paramecium, for example, that enables all the cilia covering its body to beat harmoniously in order to propel the organism either forward or backward is quite unknown. Our ignorance we cover by saying it is a property of the living substance to adapt itself to its environment and hence to advance or retreat according to the stimuli it receives. I have no desire at this time to inquire into this question of adaptation, interesting though it be, nor have I any desire to become involved in the discussion of a possible "vital principle" at work to keep the organism behaving as a perfectly unified body capable of maintaining itself in a changing environment.

The problem I would consider very briefly has to do with the visible or physical coordinators that can be demonstrated in the laboratory and that do not lead us at once into the realm of metaphysics.

There are three well defined coordinating systems in the higher animals. The simplest is made up of the connective tissues which hold the different parts of the body in proper spatial relations to each other, which exert pressures and tensions on different parts and prevent the mechanical interference of one part with another. Ligaments and bones by their special forms and attachments prevent us from wringing our own necks. In addition to the connective tissues, which are mechanical coordinators, the muscles may also be mentioned. The muscles of the neck must be strong enough to keep the head balanced and the tongue, though it may be "hung in the middle" in some of us must not be too large to fit comfortably within the mouth cavity. The second and far and away the most complex system of coordination is the nervous system which has evolved in the course of the history of living things to an elaborateness beyond that of any other. Coordination by means of the nervous system is brought about by the peculiarly specialized property of nerve cells of transmitting certain changes along their length so that the modification of one part of the body by a stimulus is transmitted to other distant parts and throws them into activity. The exact nature of these nerve impulses is still quite problematical but there has recently come to light evidence of their chemical nature since carbon

dioxide is liberated more abundantly by a nerve along which impulses are passing than by one not active. The third form of coordinator in the body is the circulatory system by means of which materials are transported through the medium of the blood and lymph. By virtue of the rapid movement of the blood stream, all parts are furnished with a uniform nutriment and oxygen supply and washed free of accumulated wastes, and at the same time bathed with special chemical substances which modify the action of different parts of the body.

It is only very recently that the full significance of this last class of coordinators has been realized and it is to this system that I would call your attention specially. Within the past few years the energies of a great number of physiologists have been directed to certain specialized organs having the structure of glands but not communicating with any free surface by means of ducts. These organs secrete internally, directly into the blood stream from which they have derived the raw materials from which the hormone is secreted. The effects on neighboring organs of the products of other organs has been studied with great earnestness for some years, but our knowledge is still in its infancy. From the medical point of view there have been some remarkable advances made in this field. As Sir William Osler said recently, medicine has made no more brilliant advance than in the cure of certain diseases of these ductless glands.

One of the most important hormones which is produced by every living cell in the body is carbon dioxide. This is the normal product of cellular activity and affords a kind of measure of the vitality of a part. Resting, inactive cells produce comparatively little; actively contracting muscles or secreting glands produce large quantities. This waste matter, the product of the metabolism of the cells, is poured into the blood to be eliminated finally in the lungs. But before it is finally got rid of, it stimulates the respiratory center of the brain which activates the respiratory muscles. The more active the respiratory center, the more rapid and deep is the respiration. There is a most perfect coordination between the respiratory activity and the muscular activity of the body generally so that the quantity of carbon dioxide in the blood is maintained practically constant. Although breathing is under the control of the will within limits, we ordinarily respire involuntarily and unconsciously, and we take a breath only when the blood reaching the respiratory center of the brain contains an excess of carbon dioxide and stimulates it to greater activity; a fact which may be proved by any one most readily. Sitting quietly with watch in hand, the experimenter breathes rapidly and moderately deeply for from one half to one minute thus ventilating the lungs thoroughly. Then without trying to hold the breath he will note how long an interval passes before the slightest impulse to breathe is felt. In this case, by the thorough ven-

tilation of the lungs more than the normal quantity of carbon dioxide passes out of the blood and is exhaled so that the blood reaching the respiratory center is abnormally poor in CO_2. The interval, until the impulse to breathe again is felt, represents the time it takes for carbon dioxide to accumulate in the blood to the normal amount. Conversely, the inhalation of carbon dioxide leads to more rapid and forced breathing because of the over-stimulation of the respiratory center. Before the young mammalian is born it does not breathe air through the lungs; in fact, its lungs do not begin to function until the infant is separated from the maternal blood circulation and the carbon dioxide produced by the activity of its cells has accumulated sufficiently in the blood to throw the respiratory center into activity and in consequence the muscles by means of which the air is changed in the lungs. This, of course, is simply a matter of seconds.

That it is the composition of the blood which determines the activity of the respiratory muscles may also be demonstrated in another way. The lungs of birds are so connected with air spaces which extend through the bones that it is possible to pass a continuous stream of fresh air through them by connecting the cut end of one of the larger bones with a suitable pump. Under the circumstances, the bird makes not the slightest respiratory movement for an indefinite time since its blood is maintained in a perfectly normal arterial condition, with an abundance of oxygen in it and unable to stimulate the respiratory center.

Another most clearly proved chemical harmonizer, which makes the pancreas secrete at the moment its secretion is needed, is the substance secretin which is formed in the intestine by the stimulation of the intestinal wall by an acid. This substance is carried to the pancreas in the circulation and causes that organ to secrete pancreatic juice, the most important digestive juice. The stimulation of the pancreas by some material transported thither rather than by nervous stimulus has been proven in several ways. All the nerves connected with an isolated loop of intestine are cut, so that no impulses can pass from the stimulated part of the intestine, but the blood vessels are left intact. An acid, like the acid of the gastric juice, is introduced into this isolated part of the intestine and the flow of pancreatic juice is noted. The increase of the flow of pancreatic juice is quite as great as when the nerves are not cut. Again, it has been found that the blood leaving the intestine which has been stimulated by an acid has the power of stimulating the flow of pancreatic juice in a second animal into whose blood vessels this blood is injected. It has been demonstrated also that acid in the blood alone has no such effect on the flow of pancreatic juice. Here we have a clear example of harmonious, purposeful action; namely, the secretion of pancreatic juice at the time that the contents of the stomach

pass into the intestine, effected through a definite chemical substance manufactured in the intestine under the influence of an acid and transported to the pancreas.

Some very interesting cases of accurate coordination through chemical means have been noted in the development of the embryo from the egg. Let me illustrate with some experiments on the development of the eye of the tadpole. You may recall that the fine coordination displayed by the development of the eye was a stumbling block to Darwin in the way of the general acceptance of the theory of natural selection. The experimenter, however, has shown that to some extent this beautiful and complex coordination of parts is accomplished by chemical substances produced by certain organs. Before explaining the experiments, it will be necessary to describe very briefly the embryology of the eye. At a very early age before the body form of the embryo has been established and before many organs have been laid down, the brain broadens out in the form of a small conical projection on each side. The apex of this cone finally reaches the level of the skin. This swelling is known as the optic vesicle and from it is derived the portion of the eye which is sensitive to light, the retina. The bit of skin in contact with the apex of the optic vesicle sinks down beneath the surface like a little cup or pit, pushing the optic vesicle down with it, just as one might push in one side of a rubber ball with the thumb. The margins of this depression finally close together forming a hollow ball which becomes separated from the skin. This later becomes the lens of the eye. These are facts which could be demonstrated to you in a half hour in the laboratory. The lens of the eye, of course, is very different from the skin and if we did not know its embryological history we would hardly guess that it was derived from the skin. The embryologist used to think that the bit of skin which came to lie directly over the optic vesicle was unlike the rest of the skin, being endowed with special powers of forming the crystalline lens of the eye, and the mystery was, how it chanced that these lens-potentialities were accumulated at exactly the right spot and that there did not occur at times stray lenses scattered about on other parts of the body. The experimentalist, however, who has done so much to destroy illusions and push further back the limits of the mysterious, has shown that the formation of the lens depends entirely upon the contact of the optic vesicle and that any part of the skin under the influence of this structure will develop into a lens. Under the dissecting microscope with very fine needles it is possible to operate on the young tadpole before the eye is formed and to transplant the optic vesicle to some other part of the body. The results of this very drastic treatment are that any part of the skin which overlies the transplanted optic vesicle will form a lens. Any embryonic skin of the right age apparently has the power

of developing into a lens under the proper stimulus. In fact the experimenter has gone so far as to graft two tadpoles of different species in such a way that the optic vesicle of one comes to lie directly beneath the skin of the abdomen of the other. But even here the skin of the abdomen of the strange tadpole developed a lens in a perfectly orthodox fashion.

Darwin today would not be so mystified over the quèstion of how the different layers of tissue of different degrees of transparency and refraction chanced to occur in the right relations to each other to form a complex purposeful organ like the eye. The difficulty to-day is to explain how the skin of the embryo is endowed with such wonderful powers and how the optic vesicle is able to call forth such a complex response.

The phenomenon of internal secretion, that is, the discharge of substances manufactured by an organ directly into the blood passing through the organ and not to a free surface, was discovered by the great French physiologist, Claude Bernard, in 1876, when he demonstrated that the liver manufactures sugar and pours it constantly into the blood passing through that organ. Besides these organs which only incidentally to other functions secrete into the blood, like the liver, the pancreas, the sex glands and the developing fetus in the mammal, there are certain organs specialized for this purpose alone. These are called ductless glands, because they have no outlet to a surface, or endocrine organs, that is, organs secreting to the inside. The most important of these are the pituitary body, situated on the under side of the brain next to the roof of the pharynx and tucked into a little pocket on the floor of the skull; the pineal body, on the upper side of the brain but buried deep in the crease between the two halves of the cerebrum; the thyroid gland situated on the front of the throat just below the "Adam's apple" and enlarged in goitre; the thymus gland situated in front of the heart, from which the true "neck sweetbreads" are taken: and the adrenal bodies situated just above the kidneys.

The ductless glands just enumerated seem to have the most marked effect upon growth, development, and nutrition. Some of them, especially the adrenal body, also have a marked effect upon the blood pressure.

The thyroid gland influences powerfully the growth of the body and the rate at which the mature state is reached.

A few years ago one of our American experimenters showed that the growth of the tadpole may be stopped almost immediately by feeding thyroid gland. At the same time that the increase in size ceases, the transformation of the tadpole into a frog goes on with increased speed. Tadpoles were obtained which had the fore legs in fifteen days from the time that they issued from the egg while ordinarily they ap-

pear only after about four months. The action of the thyroid gland on the human subject seems to be somewhat different from that just described although its action affects development. The distressing disease, cretinism, characterized by the squat stature and low mentality, with puffy skin and bleary eyes, is the result of insufficient activity of the thyroid which may be made good by feeding thyroid glands from oxen or sheep. Thyroid feeding is sometimes employed to reduce obesity, as under its stimulus more rapid oxidation of the tissues takes place. Thyroid fed to immature rats retards growth. Rats fed thyroid gland do not gain weight as rapidly as normal ones. To one-half of a litter kept under conditions as nearly like the other half as possible were fed small quantities of thyroid. In three or four days the thyroid individuals gained only 4.2 gms. on the average as compared with 10.1 gms. for those not specially fed.

Another organ which has a very marked effect upon growth is the pituitary body, a small structure which is attached to the under side of the brain and which originates in the embryo from the roof of the mouth. When this gland secretes more than the normal amount in childhood before growth is completed, gigantism results and the child continues its growth beyond the normal and becomes a giant. The overactivity of the same gland later in life when normal growth is complete leads to a disease known as acromegaly in which the extremities of the body alone grow abnormally. Conversely, if the pituitary body is removed or if it is not sufficiently active on account of disease, there follows a condition known as infantilism, characterized by the development of much fat beneath the skin and more or less atrophy of the sexual organs.

Regarding the function of the thymus we are especially in the dark. As is well known it degenerates before the adult condition is attained and it may be removed from young animals apparently without causing any modification in the rate of growth or any special symptoms of any kind. The feeding of thymus gland to tadpoles has been found, however, to have a marked effect upon growth, prolonging the period of growth and inhibiting the metamorphosis of the tadpole.

The action of the adrenal bodies has already been alluded to. The removal of the organs is followed by death in about 36 hours in the mammals ordinarily used for experimental purposes like dogs, cats, rabbits, and the like. When the adrenals are diseased, a number of definite symptoms known as Addison's disease appear; the skin assumes a coppery color, there is great muscular weakness and lowering of the temperature of the body. The application of the extract of the gland—adrenalin—to a bleeding or inflamed part is followed at once by a constriction of the capillary blood vessels and a blanching of the part. This property, of course, makes the extract of great value to the sur-

geon in operations in which there is profuse bleeding from many tiny blood vessels, like many operations on the nose. So powerful is the hormone of the adrenal body that one part of adrenalin in one hundred million of Ringer's solution produces marked effect on the contraction of involuntary muscle.

The pineal body, which Descartes thought was the seat of the soul of man, has a most obscure function which cannot at present be clearly defined. The removal of the organ is very difficult without serious injury in the operation. When it is successfully removed without injury to the animal there has been found to be in some cases a precocious development of the sexual organs but in other experiments the effects have been negative.

The ductless glands seem to be more or less closely related to each other in function so that the removal of one may be accompanied by changes in others, but it is apparent that there is much still to be learned regarding the exact working of these very subtle organs. The fact, however, that the precise functions of some of these organs have not been exactly determined does not mean that they have little effect upon the organism as a whole. What has just been said regarding the pituitary, suprarenals, and thyroids shows that the contrary is the fact.

Considering the organs which only incidentally secrete internally, the pancreas exhibits a very interesting harmonizing action. The function of the pancreas is not only the secretion of a digestive juice which performs the great bulk of the digestion of food in the intestine, but also the secretion into the blood of something which enables the sugar absorbed from the intestine to be stored in the liver until needed in the active organs of the body. If the pancreas is removed entirely, diabetes appears at once due to the failure of the liver to remove the sugar from the blood. In order to determine that this condition is not due simply to the elimination of the pancreatic juice from the alimentary canal, the experiment has been made of simply tying off tightly the duct leading from the pancreas to the intestine, but not interfering with the circulation of the blood through the organ, and also of grafting the pancreas which has been cut out, on some other part of the body so that blood will pass through it. In both these experiments diabetes does not appear and we must conclude that the pancreas secretes into the blood a substance which enables the liver to store up grape sugar.

The effects of the reproductive organs upon the body as a whole have been known in a general way from time immemorial. Especially in the male sex have the reproductive organs been removed for economic or social reasons. Emasculation in the human subject when performed in early youth prevents those changes from taking place which normally occur at puberty, such as growth of hair on various parts of the body, the growth of the larynx with the consequent lowering of the pitch of

the voice, and the growth of the chest. It has been said also that in oxen and horses the removal of the male sexual organs at an early age causes the haunch bones to change to the female type. It has been known for years that if the very young male deer is castrated, the antlers never appear and if the operation is performed when the antlers have already begun to develop, they fail to reach their normal size and remain covered with the velvet, like young antlers. In the adult deer castration causes the antlers to be shed precociously and they are replaced, if at all, by imperfect antlers which are never renewed. Thus we see that the complex changes involved in the development of the antlers are dependent upon the presence of something supplied by the sex glands of the male.

The female sex organs are no less potent in determining the course of development. One experimenter removed the testes of a guinea pig and a rat and replaced them with ovaries from a female. The presence of the ovaries in the body of the emasculated male led to a remarkable development of the mammary glands and a change in the proportions of the skeleton to more nearly those of the female. Another important change is that the size of the feminized males is less than that of the normal castrated males, showing that there is something produced by the ovary which prevents the normal growth of the male. These experiments are not numerous but they indicate something of the power of the sexual organs to determine by their internal secretions the growth and relative size of parts of the body.

Equally marked effects have been noted in the case of birds. The desirable effects of removing the male organs have been known for many years and capons have been highly esteemed as delicacies. It is well known, of course, that the removal of the male organs in poultry leads to increased size and deposition of fat. Notwithstanding, the male plumage with all the secondary sexual characters appear as in normal birds. During the past few years the experiment of removing completely the ovaries from a female bird has been successful. In this case the ovaries were removed from a very young Mallard duck, in which the plumage of the male and female are very different. It was found that the plumage of the spayed female became similar to that of the male.

The developing fetus within the uterus of the female exercises an important effect upon the development of the milk glands so that the latter are able to supply an abundant nourishment for the young which are to be born shortly. This effect is produced by the discharge of some substance into the blood stream of the mother through the placenta. This has been demonstrated with rabbits by injecting into the blood vessels of a virgin rabbit, in which the milk glands are practically invisible, the extract of a fetus taken from a pregnant female.

The injection is followed by a rapid growth of the glands. That this effect is produced directly upon the milk glands and not indirectly through the action of the uterus and ovaries has been shown by making the injection after the removal of those organs. The effect upon the milk glands is just as marked as when ovaries and uterus are present. A further confirmation of the harmonizing of the activity of the mammary glands and the needs of the body through hormones is afforded by the famous case of the Blazek sisters who were joined like the Siamese twins with blood vessels united but with entirely separate nervous systems. In spite of the absence of nervous connections between the two, pregnancy in the one produced a normal growth of the mammary glands of the other, and with the birth of the child the secretion of milk by the glands of the two sisters occurred. A third method of demonstrating the chemical control of the mammary glands is by severing the spinal cord at the level from which the nerves going to the glands are given off, so that the nervous connections between the two ends of the mammary glands in such an animal as the dog whose glands extend along the entire length of the abdomen, are severed. In spite of this separation, however, secretion occurs simultaneously in all the glands.

Our knowledge of the presence and action of hormones in the blood is in its infancy. There can be little doubt that further investigations will prove that many more are working in the body than we dream of now and that their effects may be found to be of far more importance. The endocrine organs can not be supposed to allow of the complex development which the nervous system has experienced in the animal kingdom nor can it ever have the same far-reaching effects, but enough perhaps has been presented to show how the integration of the body as a whole is brought about by non-living products of cells circulating in the blood. In conclusion, however, we can hardly say that the physiologist, studying the chemical harmonizers of the body, has solved the problem of individuality, or that the conception of the animal body has been rendered more simple as a result of these discoveries. The explanation of the timely appearance of these harmonizers and the mechanism of the complex reactions to them is quite as difficult and perplexing as that of the harmonies themselves. The knowledge of these chemical bodies is an aid to us in pushing back further in the life cycle those forces or mechanical devices which are capable of producing the integrated living body, and the harmonizers of the body afford a mechanical explanation of many phenomena which in the past required a mystical or vitalistic explanation. The chemical harmonizers in their action and the response of the body to them are quite as baffling as the fact of harmonious action itself, so that pushing back the mystery only deepens it.

GRAZING PRACTICE ON THE NATIONAL FORESTS AND ITS EFFECT ON NATURAL CONDITIONS*

By CLARENCE F. KORSTIAN
U. S. FOREST SERVICE

THE statutory purposes of the national forests are to insure a perpetual supply of timber, to preserve the forest cover which regulates the flow of streams, and to provide for the use of all resources which the forests contain, in the ways which will make them of the greatest permanent good to the entire nation.[1]

Grazing on the national forests is regulated with the object of using the forage resources to the fullest extent consistent with the protection, development and use of the other resources. Since the national forests were established primarily for the protection and development of the forest resources and the protection of the watersheds, great care is taken to harmonize grazing with these primary purposes. The importance of adjusting grazing so as to secure the perpetuation of the range resources and yet not to interfere with the requirements of the other resources is emphasized in the administration of the national forests.[2] If the fundamental principles of range management, such as the proper division of the range among different classes of stock, the establishment of correct periods of grazing, stocking the range to actual carrying capacity, and securing proper management of the stock are followed in practice, actual damage to the forests will be limited to unusual cases where a combination of factors makes special treatment necessary to insure the proper protection of the forest resources and the watersheds. The forest officers in charge of the administration of grazing fully appreciate that much remains to be done in developing range management, especially in connection with the determination of the proper grazing season and methods of handling stock on the national forest ranges.

Through a series of investigations and experiments extending over

* Prepared for the Committee on the Preservation of Natural Conditions of the Ecological Society of America.

1 U. S. Forest Service. The National Forest Manual; Regulations and Instructions. 1914.

The Use Book; A Manual of Information about the National Forests. 1918.

2 Jardine, James T. and Anderson, Mark. Range Management on the National Forests. U. S. Dept. of Agri. Bull. 790. 1919.

FIG. 1. SHEET AND GULLEY EROSION ON AN OVERGRAZED RANGE IN NORTHWESTERN NEVADA. Snow lies on the bare portion in the background until early summer and the cattle follow the receding snow, eating all of the succulent vegetation before it has become established. The Forest Service has closed this watershed together with three others aggregating 20,000 acres to grazing by all classes of livestock, for a period of at least five years for the purpose of revegetating the range with palatable forage plants and of regenerating the stands of aspen on the watersheds.

FIG. 2. ASPEN SPROUTS AND A FAIR STAND OF FORAGE ON THE AREA, A PORTION OF WHICH IS SHOWN IN FIG. 1, AFTER IT HAD BEEN CLOSED TO GRAZING FOR TWO YEARS. After the aspen reproduction has become established and is out of reach of the grazing of livestock, the areas will be opened to regulated grazing and probably other areas closed for a like period. This practice will be continued until the entire Forest has been revegetated to forage plants and regenerated to aspen reproduction.

a period of years, a number of important principles of range management and management of livestock have been developed for harmonizing grazing use with the regeneration and growth of forests.[3]

A proper understanding of the forest cover in relation to the regulation of stream flow and erosion is important in range management, since "cover" in the sense used includes the tree cover, the herbaceous and shrubby cover, and the surface soil with its comparatively rich admixture of organic matter.[4] Over-grazing frequently results in packing the soil, decreases its power of absorbing and holding precipitation, and causes the partial or complete destruction of the ground cover, a condition almost invariably associated with erosion and the reversion of the native vegetation to a lower successional stage.[5] In this case the reestablishment of the more permanent type of vegetation is prevented until, with the return of the original fertility of the soil, the sub-climax species again appear.

The grazing of livestock may either retard or promote the development of the vegetative cover and cause either retrogression or progression of the types, depending chiefly upon the closeness with which the herbage is grazed annually and the time of cropping.[6] Continuous premature and too close grazing not only favor degeneration of the cover and ultimately the destruction of the vegetation, but also tend to impair the fertility of the soil through erosion. On the other hand, deferred-and-rotation grazing, that is, grazing the depleted range only after seed maturity and later applying this practice in rotation to all the other parts of the range favors progressive succession.[7] The effects of grazing upon plant succession depend not only on the character and intensity of grazing, but also upon the type of vegetation. However, it may be said that properly regulated grazing shows a tendency to hold

[3] Cf.

Sampson, Arthur W. and Dayton, William A. Relation of Grazing to Timber Reproduction. U. S. Forest Service Review of Forest Service Investigations, Vol. 2, pp. 18-24, 1913.

Hill, Robert R. Effects of Grazing Upon Western Yellow Pine Reproduction in the National Forests of Arizona and New Mexico. U. S. Dept. of Agri. Bull. 580, 1917.

Sparhawk, W. N. Effects of Grazing Upon Western Yellow Pine Reproduction in Central Idaho. U. S. Dept. of Agri. Bull. 738, 1918.

Sampson, Arthur W. Effect of Grazing Upon Aspen Reproduction. U. S. Dept. of Agri. Bull. 741, 1919.

[4] Reynolds, Robert V. R. Grazing and Floods: A Study of Conditions in the Manti National Forest. U. S. Forest Service Bull. 91, 1911.

[5] Sampson, Arthur W., and Weyl, Leon H. Range Preservation and its Relation to Erosion Control on Western Grazing Grounds. U. S. Dept. of Agri. Bull. 675, 1918.

[6] Sampson, Arthur W. Plant Succession in Relation to Range Management. U. S. Dept. of Agri. Bull. 791, 1919.

FIG. 3. A BADLY OVERGRAZED AREA ON A POORLY MANAGED CATTLE RANGE ADJACENT TO THAT SHOWN IN FIG. 2 IN NEED OF REMEDIAL MEASURES. The complete absence of aspen reproduction and the dearth of palatable forage plants is evidenced by the barren appearance of the surface of the ground. Erosion is also evident.

FIG. 4. AN OLD BURN IN A LODGEPOLE PINE FOREST IN CENTRAL IDAHO WHICH IS ADEQUATELY RESTOCKING WITH NATURAL REPRODUCTION. The forage is being properly utilized as a result of regulated grazing, so that no injury is resulting to either the forest tree seedlings or to the forage plants themselves.

the vegetative succession in one of the sub-climax, or occasionally climax stages of the herbaceous and shrubby vegetation, but should offer little or no interference with the climax forest type, since grazing is very frequently excluded from forest areas being regenerated.

The value of regulated grazing as a means of fire protection is recognized in the utilization of the annual growth of grass, which, if not utilized, becomes dry and inflammable, and a real cause of forest fires. [8] It is thus seen that grazing in itself is beneficial as a control of fires. In addition to this, the extensive work in forest fire prevention and suppression is a very important factor in promoting and maintaining climax types of vegetation.

With the development of the livestock industry in the West, came the economic necessity of controlling predatory animals. The decrease in their number, especially of the coyotes, probably resulted in an increase in the number of rodents, many of which are active range destroyers. These in turn have had to be controlled. With the decrease in the number of predatory animals there should be an increase in the number of game animals; but this has been largely, if not wholly, offset by the increased number killed by hunters within recent years.

The national forest policy provides that the protection and development of the wild life of the forest must go hand in hand with the development and management of the range resources for use by domestic stock. Before opening up new range to domestic stock the use or probable use of the area by game is carefully considered.

Suitable camping grounds are provided on the national forests and are given sufficient protection from grazing to preserve their natural attractiveness for the recreational use of campers and tourists.

The conserving of the national parks in an unmodified condition in the interests of natural history and research and the desirability of maintaining the original balance between the plant and animal life has already been emphasized.[9] The management of areas for game and fish production will doubtless cause disturbances and readjustments in

[7] Sampson, Arthur W. Range Improvement by Deferred and Rotation Grazing. U. S. Dept. of Agri. Bull. 34, 1913.

Sampson, Arthur W. Natural Revegetation of Range Lands Based upon Growth Requirements and Life History of the Vegetation. Journal of Agricultural Research, Vol. 3, No. 2, pages 93 to 148, 1914.

Jardine, James T. Improvement and Management of Native Pastures in the West. U. S. Dept. of Agri. Yearbook Separate 678, 1915.

[8] Graves, Henry S. Grazing and Fires in National Forests. American Forestry 17:435. 1911.

Hatton, John H. Livestock Grazing as a Factor in Fire Protection on the National Forests. U. S. Dept. of Agri. Circ. 134, 1920.

[9] Grinnell, Joseph and Storer, Tracy I. Animal Life as an Asset of National Parks. Science, N. S. 44:375-380, 1916.

FIG. 5. AN OPEN STAND OF LODGEPOLE PINE IN CENTRAL IDAHO ON AN AREA WHICH IS BEING GRAZED TOO HEAVILY BY LIVESTOCK. Note the absence of forage plants and the flattened, bushy shape of the lodgepole pine seedlings, which is not characteristic of this species, due to being browsed by the stock. The injury was eliminated, and the range is being restored through properly regulated grazing based on the scientific principles of range management as worked out by the grazing specialists of the Forest Service.

FIG. 6. YOUNG DEER ON GARDINER RIVER, MONTANA. The concentration of game animals on winter ranges may result in over-grazing and even eliminate certain desirable forage plants from the range.

the ecological balance between the plant and animal life, both terrestrial and aquatic. The introduction of exotic species may become a dangerous factor in disturbing the original balance, even to the extent of assuming economic proportions. The uncontrolled increase of game animals on game preserves may produce conditions very similar to those resulting from the grazing of domestic stock. However, in most cases the number of game animals on any range should be limited to the number which the range will carry through the winter.

FIG. 7. AREA IN BIG COTTONWOOD CANYON ON THE WASATCH NATIONAL FOREST IN CENTRAL UTAH WHICH IS CLOSED TO LIVESTOCK GRAZING BECAUSE IT IS ONE OF THE MAIN SOURCES OF SALT LAKE CITY'S MUNICIPAL WATER SUPPLY AND ALSO ON ACCOUNT OF ITS IMPORTANCE FOR RECREATIONAL USE.

In rendering the secondary uses of the national forests compatible with the primary uses and in harmonizing the secondary uses, it frequently becomes necessary to close areas to grazing as, for example, watersheds which comprise important sources of municipal water supply; recreational areas and those of unusual scenic attractiveness, such as the national monuments; areas on which the range is needed for important game animals: and forest areas in the course of regeneration. From the list of areas on which natural conditions are now being preserved, [10] it is seen that the forest areas are of considerable size.

[10] Compiled by the Committee on Preservation of Natural Conditions of the Ecological Society of America and to be published in the near future.

THE PROGRESS OF SCIENCE

HELMHOLTZ AND VIRCHOW

One hundred years ago were born in Prussia Hermann Helmholtz and Rudolf Virchow, the former in Potsdam on August 31, 1821, the latter in an obscure village of Pomerania on October 13, 1821.

The University of Berlin was opened in 1810 after Prussia had lost by the peace treaty of Tilsit the University of Halle, which Napoleon included in his new kingdom of Westphalia. Germany, defeated in war, required to pay an immense indemnity, its army limited to 42,000, turned its energies to education and to science. Both Helmholtz and Virchow were students of medicine in Berlin, and later became professors in the university. Their genius was born with them, but the stimulus and the opportunity to apply it to the advancement of science must in large measure be attributed to the spirit of the university founded by Humboldt and his associates when the political fortunes of Prussia were at low ebb.

Helmholtz was the son of a gymnasium teacher, his mother, Caroline Penne, being a descendant of William Penn. After a childhood of ill health, he studied medicine and was for four years a military surgeon; for a year he was teacher in the Berlin Academy of Fine Arts, and afterwards from 1849 to 1855 professor of physiology at Königsberg. He was professor at Bonn for three years and was then professor of physiology at Heidelberg from 1858 to 1871, when he was transferred to Berlin as professor of physics. In 1888 he was made president of the Reichsanstalt, organized under his direction. All possible academic and national honors were conferred upon him.

A list of von Helmholtz's contributions to science would fill many pages. The essay on the conservation of energy was printed in 1847. Researches of great range and importance, including the invention of the ophthalmoscope, led to his two epoch-making books on physiological psychology—"Tonempfindungen" (1862) and "Physiologische Optik" (1867). Helmholtz always continued his work in physiological psychology, but his transfer from a chair of physiology to one of physics represented a change in his main interests. His great contributions to mathematical physics, especially electrodynamics, are of almost unparalleled importance.

Virchow more than any other one man established the science of pathology and made it possible for medicine to become an applied science. Only second in importance to his contributions to pathology was his work in anthropology which covered all branches of the science. His scientific work was singularly complete. He made numerous and exact observations and experiments; he deduced from them wide-reaching theories; he conducted an important journal for more than fifty years; he wrote text-books, summaries of scientific advances and books popularizing science; he established a school to which students came from all parts of the world, while at the same time taking part in the education of the people; he founded a great museum and took a leading part in scientific societies; he applied science directly to human welfare.

It is almost incredible that among these multifarious scientific activities Virchow should have been one of the leading statesmen of his country. He was a member of the municipal council of Berlin for more than forty

From a drawing by Lembach (1894)

HERMANN VON HELMHOLTZ

Rud. Virchow

years, and through him the hygienic conditions of the capital were revolutionized. He was from 1862 a member of the Prussian chamber and was for twenty-five years chairman of the committee on finance. He was leader of the radical party in the Reichstag. In his public career he opposed centralization, autocracy and war, and advocated all measures for the welfare of the people. He was at one time compelled to leave the University of Berlin owing to his political activity, but his personality and eminence were such that he was recalled to a professorship in 1856, and he was thereafter the preeminent representative of academic freedom.

THE INTERNATIONAL INSTITUTE OF AGRICULTURE

The president of the International Institute of Agriculture at Rome has transmitted to the Secretary of Agriculture, through the State Department, a copy of resolutions adopted in April, 1921, by the permanent committee of the institute, authorizing the conferring of the title "donating member" upon any person who makes a gift, donation, or contribution to the institute amounting in value to 10,000 Italian lire, which at normal rates of exchange is equivalent to about $2,000.

The International Institute of Agriculture was established as the direct result of the efforts of David Lubin, a successful merchant of California, with the active support of the King of Italy, who foresaw the advantages which would accrue to agriculture, commerce, and industry from an international clearinghouse for systematically collecting and disseminating official information supplied by the various governments of the world on agricultural production, consumption, movements, surpluses, deficits, and prices of agricultural products, transportation, plant and animal diseases and insect pests, rural credits and insurance, standard of living, wages and hours of labor on farms, cooperative organizations of farmers, legislation affecting agriculture, and similar information. The international treaty was drafted at Rome on June 7, 1905, and has since been ratified by more than 60 governments.

The institute survived the trying period of the World War and is now entering upon a period of expansion and increased usefulness. Its work benefits all peoples. In accordance with the recent action of the permanent committee, which is made up of delegates from the adhering governments and serves as a board of directors of the International Institute of Agriculture, citizens of the United States and other countries who are in sympathy with the purposes of the institute have an opportunity to contribute to its support and development and to receive permanent recognition therefor as "donating members" by having their names and nationality and the date of their donation inscribed on a marble tablet which will be placed in a conspicuous position in the halls or vestibule of the marble palace occupied by the institute, situated in a beautiful park on an elevation overlooking the Eternal City. Such donations can be made either through the Secretary of Agriculture, the Secretary of State, or the American delegate to the International Institute of Agriculture, Rome, Italy.

THE NATIONAL GEOGRAPHIC SOCIETY'S GIFTS OF BIG TREES

The trustees and officers of the National Geographic Society announce to members that the society has been continuing its efforts, begun in 1916, to preserve the Big Trees of Sequoia National Park. By a final purchase in April, 1921, of 640 acres of land in Sequoia National Park, these famous trees, oldest and most massive among all living things, the only ones of their kind in the world, have been saved; they will not be cut down and converted into lumber.

Were a monument of human erection to be destroyed, it might be replaced; but had these aborigines of American forests been felled, they would have disappeared forever. The Big Trees could no more be restored than could those other survivals of indigenous American life, the red man and the buffalo, should they become extinct.

Members of the National Geographic Society will recall that, in 1916, Congress had appropriated $50,000 for the purchase of certain private holdings in Sequoia National Park, but the owners declined to sell for less than $70,000. In that emergency the National Geographic Society took the first step toward saving the Big Trees by subscribing the remaining $20,000. Thus 667 acres were purchased. The society's equity in them was conveyed to the government, and this tract became the property, for all time, of the American people.

In 1920, inspired by the first benefaction, three members of the society gave the society sums equivalent to the purchase price of $21,330 necessary to acquire three more tracts, aggregating 609 acres. Thus the original area of Sequoias saved from destruction was almost doubled.

There still remained one other important private holding in Sequoia National Park amounting to 640 acres. Through this tract, which is covered by a splendid stand of giant sugar-pine and fir, runs the road to Giant Forest. To acquire this approach to the unique forest and to eliminate the last of the private holdings in this natural temple, the National Geographic Society and friends of the society, in 1921, contributed $55,000, with which the tract was purchased. On April 20, 1921, it was formally tendered in the name of the society, through Secretary of the Interior Albert B. Fall, to the American people.

This sum of $55,000 includes $10,000 from the tax fund of Tulare County, California, within which the Sequoia National Park is situated, a practical evidence that the people closest to the park are alive to the importance of our government owning the land.

FIELD WORK OF THE SMITHSONIAN INSTITUTION

The Smithsonian Institution has issued its annual exploration report describing its scientific field work throughout the world in 1920. Twenty-three separate expeditions were in the field carrying on researches in geology, paleontology, zoology, botany, astrophysics, anthropology, archeology, and ethnology, and the regions visited included the Canadian Rockies, fourteen states of the United States, Haiti, Jamaica, four countries of South America, Africa from the Cape to Cairo, China, Japan, Korea, Manchuria, Mongolia, Australia, and the Hawaiian Islands.

Secretary Walcott continued his geological work in the Cambrian rocks of the Canadian Rockies in the region northeast of Banff, Alberta. The particular questions involved in the season's research were settled satisfactorily and some beautiful photographs of this wild and rugged region obtained. Other geological field work was successfully carried on in various states of the United States by members of the staff.

In astrophysical research the institution was unusually active. Through the generosity of Mr. John A. Roebling of New Jersey, the Smithsonian solar observing station located on the plain near Calama, Chile, was moved to a near-by mountain peak, where the observations will be unaffected by the dust and smoke, and a new station was established on the Harqua Hala Mountain, Arizona, probably the most cloudless region in the United States. From daily observations of the radiation of the sun at these two widely separated stations, it is hoped to establish definitely the value of the

"solar constant" observations in forecasting weather. Dr. C. G. Abbott, director of the work, also describes the successful operation on Mt. Wilson, California, of a solar cooker devised by him. With this apparatus it was possible, using only the sun's heat, to cook bread, meat, vegetables, and preserves.

Mr. H. C. Raven represented the Smithsonian on an extensive collecting expedition through Africa from south to north. Although many difficulties were encountered, among others a railway wreck in which two members of the expedition were killed, Mr. Raven shipped to the institution much interesting zoological material, which was greatly needed for purposes of comparison in working up the famous Roosevelt and Rainey collections already in the National Museum. Many interesting photographs of the animals, the natives, and the country itself are shown in this account and in that of Dr. Shantz, who accompanied the expedition as a botanical collector. In Australia, a Smithsonian naturalist collected, through the generosity of Dr. W. L. Abbott, specimens of the fast disappearing remarkable fauna of the continent, while Dr. Abbott himself secured a great number of plants, birds, and other natural history material for the National Museum, in various regions of Haiti. A number of other zoological and botanical expeditions are briefly described and illustrated.

BIRDS BANDED BY THE BIOLOGICAL SURVEY

Persons engaged in outdoor activities, whether or not trained bird observers, are requested to cooperate with the Bureau of Biological Survey, United States Department of Agriculture, by furnishing data to supplement the bird-banding work that is being conducted by the bureau. When any one happens to capture a banded bird or to come upon one that has been hurt or killed, it will be of great assistance to the investigations of the department to have a report made of the facts by returning the band (if the bird is dead; otherwise the band should not be removed, but its number noted), together with details as to when and where the bird was found.

The aluminum bands issued by the Biological Survey carry the abbreviation "Biol. Surv." and a serial number on one side, and "Wash., D. C." on other. But as other bands have been used on a large number of birds by various individuals and institutions, it would be advisable for anyone finding a bird that carries a band not marked as above indicated, or of which the address is not clearly understood, to forward the information to the Biological Survey, where every effort will be made to locate the person responsible. These bands are placed on the bird's tarsus, the bare portion of the leg immediately above the toes.

Experts in bird work are using the banding method to solve a variety of problems relative to the migrations and life histories of our native birds which are thus approached from the aspects of the individual birds. Some of the more important questions that can be solved by banding operations are: How fast do the individuals of any species travel on their periodic migrations; does any one flock continue in the van or is the advance made by successive flocks passing one over the other in alternate periods of rest and flight? Do individuals of any species always follow the same route, and is it identical for both spring and fall flights? Do migrating birds make the same stop-overs every year to feed? How long do birds remain in one locality during the migration, the breeding, or the winter seasons? Do birds adopt the same nesting area, nest site, and winter quarters during successive seasons? For how many broods will one pair remain matted, and which bird, if not both, is attracted next year to the old nesting site? How

far from their nests do birds forage for food; and, after the young have left the nest, will the parent birds bring them to the feeding and trapping station? How long do birds live?

A minimum of 100,000 banded birds is planned, from which it is hoped that valuable information will be obtained in regard to the habits of migratory birds.

SCIENTIFIC ITEMS

We record with regret the death of Winthrop E. Stone, since 1900 president of Purdue University, and previously professor of chemistry; of Edmond Perrier, director of the Paris Museum of Natural History; of Gabriel Lippman, professor of physics in the University of Paris, and of Professor Viktor von Lang, formerly professor of physics at Vienna.

The Mathematical Association of America and the American Mathematical Society will hold their summer meetings at Wellesley College, September 6-7 and 7-9, respectively. Two joint sessions will be devoted to a symposium on "Relativity." On the afternoon of the seventh, Professor Pierpont, of Yale University, will give a paper entitled "Some mathematical aspects of the theory of relativity," while on the forenoon of the eighth, Professor Lunn, of the University of Chicago, will speak on "The place of the Einstein theory in theoretical physics."

The Municipal Observatory at Des Moines, Iowa, which is said to be the only municipal observatory in the world, was opened on August 1. The observatory building is to be equipped by Drake University with an 8-inch equatorial telescope. It is to be under the control of the university and open to the public at least three times a week, and at any other time when occasion may warrant.

A new forest experiment station, the first in the Eastern States, has been established at Asheville, N. C., by the Forest Service of the United States Department of Agriculture. Steady depletion of the Southern Appalachian timber supply has been responsible for the location of this station in the East, and the object of the work to be conducted will be to secure the information needed by foresters to determine the best methods of handling forest lands in the southern mountains.

THE SCIENTIFIC MONTHLY

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THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE[1]

THE CONSTITUTION OF MATTER

By Sir T. EDWARD THORPE, C.B., F.R.S.

PRESIDENT OF THE ASSOCIATION

THE molecular theory of matter—a theory which in its crudest form has descended to us from the earliest times and which has been elaborated by various speculative thinkers through the intervening ages, hardly rested upon an experimental basis until within the memory of men still living. When Lord Kelvin spoke in 1871, the best-established development of the molecular hypothesis was exhibited in the kinetic theory of gases as worked out by Joule, Clausius, and Clerk-Maxwell. As he then said, no such comprehensive molecular theory had ever been even imagined before the nineteenth century. But, with the eye of faith, he clearly perceived that, definite and complete in its area as it was, it was 'but a well-drawn part of a great chart, in which all physical science will be represented with every property of matter shown in dynamical relation to the whole. The prospect we now have of an early completion of this chart is based on the assumption of atoms. But there can be no permanent satisfaction to the mind in explaining heat, light, elasticity, diffusion, electricity and magnetism, in gases, liquids and solids, and describing precisely the relations of these different states of matter to one another by statistics of great numbers of atoms when the properties of the atom itself are simply assumed. When the theory, of which we have the first instalment in Clausius and Maxwell's work, is complete, we are but brought face to face with a superlatively grand question: What is the inner mechanism of the atom?'

If the properties and affections of matter are dependent upon the inner mechanism of the atom, an atomic theory, to be valid, must comprehend and explain them all. There cannot be one kind of atom for the physicist and another for the chemist. The nature of chemical affinity and of valency, the modes of their action, the difference in characteristics of the chemical elements, even their number, internal con-

[1] Extracts from addresses given at the Edinburgh Meeting.

stitution, periodic position, and possible isotopic rearrangements must be accounted for and explained by it. Fifty years ago chemists, for the most part, rested in the comfortable belief of the existence of atoms in the restricted sense in which Dalton, as a legacy from Newton, had imagined them. Lord Kelvin, unlike the chemists, had never been in the habit of 'evading questions as to the hardness or indivisibility of atoms by virtually assuming them to be infinitely small and infinitely numerous.' Nor, on the other hand, did he realize, with Boscovich, the atom 'as a mystic point endowed with inertia and the attribute of attracting or repelling other such centres.' Science advances not so much by fundamental alterations in its beliefs as by additions to them. Dalton would equally have regarded the atom 'as a piece of matter of measureable dimensions, with shape, motion, and laws of action, intelligible subjects of scientific investigation.'

In spite of the fact that the atomic theory, as formulated by Dalton, has been generally accepted for nearly a century, it is only within the last few years that physicists have arrived at a conception of the structure of the atom sufficiently precise to be of service to chemists in connection with the relation between the properties of elements of different kinds, and in throwing light on the mechanism of chemical combination.

This further investigation of the 'superlatively grand question—the inner mechanism of the atom,'—has profoundly modified the basic conceptions of chemistry. It has led to a great extension of our views concerning the real nature of the chemical elements. The discovery of the electron, the production of helium in the radioactive disintegration of atoms, the recognition of the existence of isotopes, the possibility that all elementary atoms are composed either of helium atoms or of atoms of hydrogen and helium, and that these atoms, in their turn, are built up of two constituents, one of which is the electron, a particle of negative electricity whose mass is only 1/1800 of that of an atom of hydrogen, and the other a particle of positive electricity whose mass is practically identical with that of the same atom—the outcome, in short, of the collective work of Soddy, Rutherford, J. J. Thomson, Collie, Moseley and others—are pregnant facts which have completely altered the fundamental aspects of the science. Chemical philosophy has, in fact, now definitely entered on a new phase.

Looking back over the past, some indications of the coming change might have been perceived wholly unconnected, of course, with the recent experimental work which has served to ratify it. In a short paper entitled 'Speculative Ideas respecting the Constitution of Matter,' originally published in 1863, Graham conceived that the various kinds of matter, now recognised as different elementary substances, may possess one and the same ultimate or atomic molecule existing in different conditions of movement. This idea, in its essence, may be said to be as old as the time of Leucippus. To Graham as to Leucip-

pus 'the action of the atom as one substance taking various forms by combinations unlimited, was enough to account for all the phenomena of the world. By separation and union with constant motion all things could be done.' But Graham developed the conception by independent thought, and in the light of experimentally ascertained knowledge which the world owes to his labours. He might have been cognisant of the speculations of the Greeks, but there is no evidence that he was knowingly influenced by them. In his paper Graham uses the terms atom and molecule if not exactly in the same sense that modern teaching demands, yet very differently from that hitherto required by the limitations of contemporary chemical doctrine. He conceives of a lower order of atoms than the chemical atom of Dalton, and founds on his conception an explanation of chemical combination based upon a fixed combining measure, which he terms the *metron*, its relative weight being one for hydrogen, sixteen for oxygen, and so on with the other so-called 'elements.' Graham, in fact, like Davy before him, never committed himself to a belief in the indivisibility of the Daltonian atom. The original atom may, he thought, be far down.

The idea of a primordial ylé, or of the essential unity of matter, has persisted throughout the ages, and, in spite of much experimental work, some of it of the highest order, which was thought to have demolished it, it has survived, revivified and supported by analogies and arguments drawn from every field of natural inquiry. This idea of course was at the basis of the hypothesis of Prout, but which, even as modified by Dumas, was held to be refuted by the monumental work of Stas. But, as pointed out by Marignac and Dumas, anyone who will impartially look at the facts can hardly escape the feeling that there must be some reason for the frequent recurrence of atomic weights differing by so little from the numbers required by the law which the work of Stas was supposed to disprove. The more exact study within recent years of the methods of determining atomic weights, the great improvement in experimental appliances and technique, combined with a more rigorous standard of accuracy demanded by a general recognition of the far-reaching importance of an exact knowledge of these physical constants, has resulted in intensifying the belief that some natural law must be at the basis of the fact that so many of the most carefully determined atomic weights on the oxygen standard are whole numbers. Nevertheless there were well authenticated exceptions which seemed to invalidate its universality. The proved fact that a so-called element may be a mixture of isotopes—substances of the same chemical attributes but of varying atomic weight—has thrown new light on the question. It is now recognised that the fractional values independently established in the case of any one element by the most accurate experimental work of various investigators are, in effect, 'statistical quantities' dependent upon a mixture of isotopes. This result, indeed, is a necessary corollary of modern conceptions of the inner mechanism of

the atom. The theory that all elementary atoms are composed of helium atoms, or of helium and hydrogen atoms, may be regarded as an extension of Prout's hypothesis, with, however, this important distinction, that whereas Prout's hypothesis was at best a surmise, with little, and that little only weak, experimental evidence to support it, the new theory is directly deduced from well-established facts. The hydrogen isotope H_3, first detected by J. J. Thomson, of which the existence has been confirmed by Aston, would seem to be an integral part of atomic structure. Rutherford, by the disruption of oxygen and nitrogen has also isolated a substance of mass 3 which enters into the structure of atomic nuclei, but which he regards as an isotope of helium, which itself is built up of four hydrogen nuclei together with two cementing electrons. The atomic nuclei of elements of even atomic number would appear to be composed of helium nuclei only, or of helium nuclei with cementing electrons; whereas those of elements of odd atomic number are made up of helium and hydrogen nuclei together with cementing electrons. In the case of the lighter elements of the latter class the number of hydrogen nuclei associated with the helium nuclei is invariably three, except in that of nitrogen where it is two. The frequent occurrence of this group of three hydrogen nuclei indicates that it is structurally an isotope of hydrogen with an atomic weight of three and nuclear charge of one. It is surmised that it is identical with the hypothetical 'nebulium' from which our 'elements' are held by astro-physicists to be originally produced in the stars through hydrogen and helium.

These results are of extraordinary interest as bearing on the question of the essential unity of matter and the mode of genesis of the elements. Members of the British Association may recall the suggestive address on this subject of the late Sir William Crookes, delivered to the Chemical Section at the Birmingham meeting of 1886, in which he questioned whether there is absolute uniformity in the mass of the atoms of a chemical element, as postulated by Dalton. He thought, with Marignac and Schutzenberger, who had previously raised the same doubt, that it was not improbable that what we term an atomic weight merely represents a mean value around which the actual weights of the atoms vary within narrow limits, or, in other words, that the mean mass is 'a statistical constant of great stability.' No valid experimental evidence in support of this surmise was or could be offered at the time it was uttered. Maxwell pointed out that the phenomena of gaseous diffusion, as then ascertained, would seem to negative the supposition. If hydrogen, for example, were composed of atoms of varying mass it should be possible to separate the lighter from the heavier atoms by diffusion through a porous septum. 'As no chemist,' said Maxwell, 'has yet obtained specimens of hydrogen differing in this way from other specimens, we conclude that all the molecules of hydrogen are of sensibly the same mass, and not merely that their mean mass is a

statistical constant of great stability.'[1] But against this it may be doubted whether any chemist had ever made experiments sufficiently precise to solve this point.

The work of Sir Norman Lockyer on the spectroscopic evidence for the dissociation of 'elementary' matter at transcendental temperatures, and the possible synthetic intro-stellar production of elements, through the helium of which he originally detected the existence, will also find its due place in the history of this new philosophy.

Sir J. J. Thomson was the first to afford direct evidence that the atoms of an element, if not exactly of the same mass, were at least approximately so, by his method of analysis of positive rays. By an extension of this method Mr. F. W. Aston has succeeded in showing that a number of elements are in reality mixtures of isotopes. It has been proved, for example, that neon, which has a mean atomic weight of about 20 and .2 consists of two isotopes having the atomic weights respectively of 20 and 22, mixed in the proportion of 90 per cent. of the former with 10 per cent. of the latter. By fractional diffusion through a porous septum an apparent difference of density of 0.7 per cent. between the lightest and heaviest fractions was obtained. The kind of experiment which Maxwell imagined proved the invariability of the hydrogen atom has sufficed to show the converse in the case of neon.

The element chlorine has had its atomic weight repeatedly determined, and, for special reasons, with the highest attainable accuracy. On the oxygen standard it is 35.46, and this value is accurate to the second decimal place. All attempts to prove that it is a whole number—35 or 36—have failed. When, however, the gas is analysed by the same method as that used in the case of neon it is found to consist of at least two isotopes of relative mass 35 and 37. There is no evidence whatever of an individual substance having the atomic weight 35.46. Hence chlorine is to be regarded as a complex element consisting of two principal isotopes of atomic weights 35 and 37 present in such proportion as to afford the mean mass 35.46. The atomic weight of chlorine has been so frequently determined by various observers and by various methods with practically identical results that it seems difficult to believe that it consists of isotopes present in definite and invariable proportion. Mr. Aston meets this objection by pointing out that all the accurate determinations have been made with chlorine derived originally from the same source, the sea, which has been perfectly mixed for æons. If samples of the element could be obtained from some other original source it is possible that other values of atomic weight would be obtained, exactly as in the case of lead in which the existence of isotopes in the metal found in various radioactive minerals was first conclusively established.

Argon, which has an atomic weight of 39.88, was found to consist

1 Clerk-Maxwell, Art. 'Atom,' *Ency. Brit.* 9th Ed.

mainly of an isotope having an atomic weight of 40, associated to the extent of about 3 per cent., with an isotope of atomic weight 36. Krypton and xenon are far more complex. The former would appear to consist of six isotopes, 78, 80, 82, 83, 84, 86; the latter of five isotopes, 129, 131, 132, 134, 136.

Fluorine is a simple element of atomic weight 19. Bromine consists of equal quantities of two isotopes, 79 and 81. Iodine, on the contrary, would appear to be a simple element of atomic weight 127. The case of tellurium is of special interest in view of its periodic relation to iodine, but the results of its examination up to the present are indefinite.

Boron and silicon are complex elements, each consisting of two isotopes, 10 and 11, and 28 and 29, respectively.

Sulphur, phosphorus, and arsenic are apparently simple elements. Their accepted atomic weights are practically integers.

All this work is so recent that there has been little opportunity, as yet, of extending it to any considerable number of the metallic elements. These, as will be obvious from the nature of the methods employed, present special difficulties. It is, however, highly probable that mercury is a mixed element consisting of many isotopes. These have been partially separated by Brönsted and Hervesy by fractional distillation at very low pressures, and have been shown to vary very slightly in density. Lithium is found to consist of two isotopes, 6 and 7. Sodium is simple, potassium and rubidium are complex, each of the two latter elements consisting, apparently, of two isotopes. The accepted atomic weight of cæsium, 132.81, would indicate complexity, but the mass spectrum shows only one line at 133. Should this be confirmed cæsium would afford an excellent test case. The accepted value for the atomic weight is sufficiently far removed from a whole number to render further investigation desirable.

This imperfect summary of Mr. Aston's work is mainly based upon the account he recently gave to the Chemical Society. At the close of his lecture he pointed out the significance of the results in relation to the periodic law. It is clear that the order of the chemical or 'mean' atomic weights in the periodic table has no practical significance; anomalous cases such as argon and potassium are simply due to the relative proportions of their heavier and lighter isotopes. This does not necessarily invalidate or even weaken the periodic law which still remains the expression of a great natural truth. That the expression as Mendeléeff left it is imperfect has long been recognised. The new light we have now gained has gone far to clear up much that was anomalous, especially Moseley's discovery that the real sequence is the atomic number, not the atomic weight. This is one more illustration of the fact that science advances by additions to its beliefs rather than by fundamental or revolutionary changes in them.

The bearing of the electronic theory of matter, too, on Prout's discarded hypothesis that the atoms of all elements were themselves built

up of a primordial atom—his *protyle* which he regarded as probably identical with hydrogen—is too obvious to need pointing out. In a sense Prout's hypothesis may be said to be now re-established, but with this essential modification—the primordial atoms he imagined are complex and are of two kinds—atoms of positive and negative electricity—respectively known as protons and electrons. These, in Mr. Aston's words, are the standard bricks that nature employs in her operations of element building.

The true value of any theory consists in its comprehensiveness and sufficiency. As applied to chemistry, this theory of 'the inner mechanism of the atom' must explain all its phenomena. We owe to Sir J. J. Thomson its extension to the explanation of the periodic law, the atomic number of an element, and of that varying power of chemical combination in an element we term valency. This explanation I give substantially in his own words. The number of electrons in an atom of the different elements has now been determined, and has been found to be equal to the atomic number of the element, that is to the position which the element occupies in the series when the elements are arranged in the order of their atomic weights. We know now the nature and quantity of the materials of which the atoms are made up. The properties of the atom will depend not only upon these factors but also upon the way in which the electrons are arranged in the atom. This arrangement will depend on the forces between the electrons themselves and also on those between the electrons and the positive charges or protons. One arrangement which naturally suggested itself is that the positive charges should be at the centre with the negative electrons around it on the surface of a sphere. Mathematical investigation shows that this is a possible arrangement if the electrons on the sphere are not too crowded. The mutual repulsion of the electrons resents overcrowding, and Sir J. J. Thomson has shown that when there are more than a certain number of electrons on the sphere, the attraction of a positive charge, limited as in the case of the atom in magnitude to the sum of the charges on the electrons, is not able to keep the electrons in stable equilibrium on the sphere, the layer of electrons explodes and a new arrangement is formed. The number of electrons which can be accommodated on the outer layer will depend upon the law of force between the positive charge and the electrons. Sir J. J. Thomson has shown that this number will be eight with a law of force of a simple type.

To show the bearing of this result as affording an explanation of the periodic law, let us, to begin with, take the case of the atom of lithium, which is supposed to have one electron in the outer layer. As each element has one more free electron in its atom than its predecessor, glucinum, the element next in succession to lithium, will have two electrons in the outer layer of its atom, boron will have three, carbon four, nitrogen five, oxygen six, fluorine seven and neon eight. As there cannot be more than eight electrons in the outer layer, the additional

electron in the atom of the next element, sodium, cannot find room in the same layer as the other electrons, but will go outside, and thus the atom of sodium, like that of lithium, will have one electron in its outer layer. The additional electron, in the atom of the next element, magnesium, will join this, and the atom of magnesium, like that of glucinum, will have two electrons in the outer layer. Again, aluminum, like boron, will have three; silicon, like carbon, four; phosphorus, like nitrogen, five; sulphur, like oxygen, six; chlorine, like fluorine, seven; and argon, like neon, eight. The sequence will then begin again. Thus the number of electrons, one, two, three, up to eight in the outer layer of the atom, will recur periodically as we proceed from one element to another in the order of their atomic weights, so that any property of an element which depends on the number of electrons in the outer layer of its atom will also recur periodically, which is precisely that remarkable property of the elements which is expressed by the periodic law of Mendeléeff, or the law of octaves of Newlands.

The valency of the elements, like their periodicity, is a consequence of the principle that equilibrium becomes unstable when there are more than eight electrons in the outer layer of the atom. For on this view the chemical combination between two atoms, A and B, consists in the electrons of A getting linked up with those of B. Consider an atom like that of neon, which has already eight electrons in its outer layer; it cannot find room for any more, so that no atoms can be linked to it, and thus it cannot form any compounds. Now take an atom of fluorine, which has seven electrons in its outer layer; it can find room for one, but only one, electron, so that it can unite with one, but not with more than one, atom of an element like hydrogen, which has one electron in the outer layer. Fluorine, accordingly, is monovalent. The oxygen atom has six electrons; it has, therefore, room for two more, and so can link up with two atoms of hydrogen: hence oxygen is divalent. Similarly nitrogen, which has five electrons and three vacant places, will be trivalent, and so on. On this view an element should have two valencies, the sum of the two being equal to eight. Thus, to take oxygen as an example, it has only two vacant places, and so can only find room for the electrons of two atoms; it has, however, six electrons available for filling up the vacant places in other atoms, and as there is only one vacancy to be filled in a fluorine atom the electrons in an oxygen atom could fill up the vacancies in six fluorine atoms, and thereby attach these atoms to it. A fluoride of oxygen of this composition remains to be discovered, but its analogue, SF_6, first made known by Moissan, is a compound of this type. The existence of two valencies for an element is in accordance with views put forward some time ago by Abegg and Bödlander. Professor Lewis and Mr. Irving Langmuir have developed, with great ingenuity and success, the consequences which follow from the hypothesis that an octet of electrons surrounds the atoms in chemical compounds.

The term 'atomic weight' has thus acquired for the chemist an alto-

gether new and much wider significance. It has long been recognised that it has a far deeper import than as a constant useful in chemical arithmetic. For the ordinary purposes of quantitative analysis, of technology, and of trade, these constants may be said to be now known with sufficient accuracy. But in view of their bearing on the great problem of the essential nature of matter and on the 'superlatively grand question, What is the inner mechanism of the atom?' they become of supreme importance. Their determination and study must now be approached from entirely new standpoints and by the conjoint action of chemists and physicists. The existence of isotopes has enormously widened the horizon. At first sight it would appear that we should require to know as many atomic weights as there are isotopes, and the chemist may well be appalled at such a prospect. All sorts of difficulties start up to affright him, such as the present impossibility of isolating isotopes in a state of individuality, their possible instability, and the inability of his quantitative methods to establish accurately the relatively small differences to be anticipated. All this would seem to make for complexity. On the other hand, it may eventually tend towards simplification. If, with the aid of the physicist we can unravel the nature and configuration of the atom of any particular element, determine the number and relative arrangement of the constituent protons and electrons, it may be possible to arrive at the atomic weight by simple calculation, on the assumption that the integer rule is mathematically valid. This, however, is almost certainly not the case, owing to the influence of 'packing.' The little differences, in fact, may make all the difference. The case is analogous to that of the so-called gaseous laws in which the departures from their mathematical expression have been the means of elucidating the physical constitution of the gases and of throwing light upon such variations in their behaviour as have been observed to occur. There would appear, therefore, ample scope for the chemist in determining with the highest attainable accuracy the departures from the whole-number rule, since it is evident that much depends upon their exact extent.

These considerations have already engaged the attention of chemists. For some years past, a small international committee, originally appointed in 1903, has made and published an annual report in which they have noted such determinations of atomic weight as have been made during the year preceding each report, and they have from time to time made suggestions for the amendment of the tables of atomic weights, published in text-books and chemical journals, and in use in chemical laboratories. In view of recent developments, the time has now arrived when the work of this international committee must be reorganised and its aims and functions extended. The mode in which this should be done has been discussed at the meeting in Brussels, in June last, of the International Union of Chemistry Pure and Applied, and has resulted in strengthening the constitution of the committee and in a wide extension of its scope.

The crisis through which we have recently passed has had a profound effect upon the world. The spectacle of the most cultured and most highly developed peoples on this earth, armed with every offensive appliance which science and the inventive skill and ingenuity of men could suggest, in the throes of a death struggle must have made the angels weep. That dreadful harvest of death is past, but the aftermath remains. Some of it is evil, and the evil will persist for, it may be, generations. There is, however, an element of good in it, and the good, we trust, will develop and increase with increase of years. The whole complexion of the world—material, social, economic, political, moral, spiritual—has been changed, in certain aspects immediately for the worse, in others prospectively for the better It behoves us, then, as a nation to pay heed to the lessons of the war.

The theme is far too complicated to be treated adequately within the limits of such an address as this. But there are some aspects of it germane to the objects of this association, and I venture, therefore, in the time that remains to me, to bring them to your notice.

The Great War differed from all previous internecine struggles in the extent to which organised science was invoked and systematically applied in its prosecution. In its later phases, indeed, success became largely a question as to which of the great contending parties could most rapidly and most effectively bring its resources to their aid. The chief protagonists had been in the forefront of scientific progress for centuries, and had an accumulated experience of the manifold applications of science in practically every department of human activity that could have any possible relation to the conduct of war. The military class in every country is probably the most conservative of all the professions and the slowest to depart from tradition. But when nations are at grips, and they realise that their very existence is threatened, every agency that may tend to cripple the adversary is apt to be resorted to—no matter how far it departs from the customs and conventions of war. This is more certain to be the case if the struggle is protracted. We have witnessed this fact in the course of the late War. Those who, realising that in the present imperfect stage of civilisation, wars are inevitable, and yet strove to minimise their horrors, and who formulated the Hague Convention of 1899, were well aware how these horrors might be enormously intensified by the applications of scientific knowledge, and especially of chemistry. Nothing shocked the conscience of the civilised world more than Germany's cynical disregard of the undertaking into which she had entered with other nations in regard, for instance, to the use of lethal gas in warfare. The nation that treacherously violated the Treaty of Belgium, and even applauded the action, might be expected to have no scruples in repudiating her obligations under the Hague Convention. April 25, 1915, which saw the clouds of the asphyxiating chlorine slowly wafted from the German trenches towards the lines of the Allies, witnessed one of the most

bestial episodes in the history of the Great War. The world stood aghast at such a spectacle of barbarism. German *Kultur* apparently had absolutely no ethical value. Poisoned weapons are employed by savages, and noxious gas had been used in Eastern warfare in early times, but its use was hitherto unknown among European nations. How it originated among the Germans—whether by the direct unprompted action of the Higher Command, or, as is more probable, at the instance of persons connected with the great manufacturing concerns in Rhineland, has, so far as I know, not transpired. It was not so used in the earlier stages of the War, even when it had become a war of position. It is notorious that the great chemical manufacturing establishments of Germany had been, for years previously, sedulously linked up in the service of the war which Germany was deliberately planning—probably, in the first instance, mainly for the supply of munitions and medicaments. We may suppose that it was the tenacity of our troops, and the failure of repeated attempts to dislodge them by direct attack, that led to the employment of such foul methods. Be this as it may, these methods became part of the settled practice of our enemies, and during the three succeeding years, that is from April 1915, to September 1918, no fewer than eighteen different forms of poison—gases, liquids and solids—were employed by the Germans. On the principle of Vespasian's law, reprisals became inevitable, and for the greater part of three years we had the sorry spectacle of the leading nations of the world flinging the most deadly products at one another that chemical knowledge could suggest and technical skill contrive. Warfare, it would seem, has now definitely entered upon a new phase. The horrors which the Hague Convention saw were imminent, and from which they strove to protect humanity, are now, apparently, by the example and initiative of Germany, to become part of the established procedure of war. Civilisation protests against a step so retrograde. Surely comity among nations should be adequate to arrest it. If the League of Nations is vested with any real power, it should be possible for it to devise the means, and to ensure their successful application. The failure of the Hague Convention is no sufficient reason for despair. The moral sense of the civilised world is not so dulled but that, if roused, it can make its influence prevail. And steps should be taken without delay to make that influence supreme, and all the more so that there are agencies at work which would seek to perpetuate such methods as a recognised procedure of war. The case for what is called chemical warfare has not wanted for advocates. It is argued that poison gas is far less fatal and far less cruel than any other instrument of war. It has been stated that 'amongst the "mustard gas" casualties the deaths were less than 2 per cent., and when death did not ensue complete recovery generally ultimately resulted. . . . Other materials of chemical warfare in use at the armistice do not kill at all; they produce casualties which, after six weeks in hospital, are discharged practically

without permanent hurt.' It has been argued that, as a method of conducting war, poison-gas is more humane than preventive medicine. Preventive medicine has increased the unit dimension of an army, free from epidemic and communicable disease, from 100,000 men to a million. 'Preventive medicine has made it possible to maintain 20,000,000 men under arms and abnormally free from disease, and so provided greater scope for the killing activities of the other military weapons. . . . Whilst the surprise effects of chemical warfare aroused anger as being contrary to military tradition, they were minute compared with those of preventive medicine. The former slew its thousands, whilst the latter slew its millions and is still reaping the harvest.' This argument carries no conviction. Poison gas is not merely contrary to European military tradition; it is repugnant to the right feeling of civilised humanity. It in no wise displaces or supplants existing instruments of war, but creates a new kind of weapon, of limitless power and deadliness. 'Mustard gas' may be a comparatively innocuous product as lethal substances go. It certainly was not intended to be such by our enemies. Nor, presumably, were the Allies any more considerate when they retaliated with it. Its effects, indeed were sufficient terrible to destroy the German *morale*. The knowledge that the Allies were preparing to employ it to an almost boundless extent was one of the factors that determined our enemies to sue for the armistice. But if poisonous chemicals are henceforth to be regarded as a regular means of offence in warfare, is it at all likely that their use will be confined to 'mustard gas,' or indeed to any other of the various substances which were employed up to the date of the armistice? To one who, after the peace, inquired in Germany concerning the German methods of making 'mustard gas,' the reply was:—'Why are you worrying about this when you know perfectly well that this is not the gas we shall use in the next war?'

I hold no brief for preventive medicine, which is well able to fight its own case. I would only say that it is the legitimate business of preventive medicine to preserve by all known means the health of any body of men, however large or small, committed to its care. It is not to its discredit if, by knowledge and skill, the numbers so maintained run into millions instead of being limited to thousands. On the other hand, 'an educated public opinion' will refuse to give credit to any body of scientific men who employ their talents in devising means to develop and perpetuate a mode of warfare which is abhorrent to the higher instinct of humanity.

This association, I trust, will set its face against the continued degradation of science in thus augmenting the horrors of war. It could have no loftier task than to use its great influence in arresting a course which is the very negation of civilisation.

THE LABORATORY OF THE LIVING ORGANISM

By Dr. M. O. FORSTER, F.R.S.

PRESIDENT OF THE CHEMICAL SECTION

AMONGST the many sources of pleasure to be found in contemplating the wonders of the universe, and denied to those untrained in scientific principles, is an appreciation of infra-minute quantities of matter. It may be urged by some that within the limits of vision imposed by telescope and microscope, ample material exists to satisfy the curiosity of all reasonable people, but the appetite of scientific inquiry is insatiable, and chemistry alone, organic, inorganic, and physical, offers an instrument by which the investigation of basal changes may be carried to regions beyond those encompassed by the astronomer and the microscopist.

It is not within the purpose of this address to survey that revolution which is now taking place in the conception of atomic structure; contributions to this question will be made in our later proceedings and will be followed with deep interest by all members of the section. Fortunately for our mental balance the discoveries of the current century, whilst profoundly modifying the atomic imagery inherited from our predecessors, have not yet seriously disturbed the principles underlying systematic organic chemistry; but they emphasise in a forcible manner the intimate connection between different branches of science, because it is from the mathematical physicist that these new ideas have sprung. Their immediate value is to reaffirm the outstanding importance of borderline research and to stimulate interest in sub-microscopic matter.

This interest presents itself to the chemist very early in life and dominates his operations with such insistence as to become axiomatic. So much so that he regards the universe as a vast theatre in which atomic and molecular units assemble and interplay, the resulting patterns into which they fall depending on the physical conditions imposed by nature. This enables him to regard micro-organisms as co-practitioners of his craft, and the chemical achievements of these humble agents have continued to excite his admiration since they were revealed by Pasteur. The sixty years which have now elapsed are rich in contributions to that knowledge which comprises the science of micro-biochemistry, and in this province, as in so many others, we have to deplore the fact that the principal advances have been made in countries other than our own. On this ground, fortified by the intimate relation of the science to a number of important industries, A. Chaston Chapman, in a series of illuminating and attractive Cantor Lectures in December, 1920, iterated his plea of the previous year for the foundation of a National Institute of Industrial Micro-biology, whilst H. E. Armstrong, in Birmingham a few weeks later, addressed an appeal to the brewing industry, which, although taking the form of a memorial

lecture, is endowed with many lively features depicting in characteristic form the manner in which the problems of brewing chemistry should, in his opinion, be attacked.

Lamenting as we now do so bitterly the accompaniments and consequences of war, it is but natural to snatch at the slender compensations which it offers, and not the least among these must be recognised the stimulus which it gives to scientific inquiry. Pasteur's *Etudes sur la Bière* were inspired by the misfortunes which overtook his country in 1870-71, and the now well-known process of Connstein and Lüdecke for augmenting the production of glycerol from glucose was engendered by parallel circumstances. That acquaintance with the yeast-cell which was an outcome of the former event had, by the time of the latter discovery, ripened into a firm friendship, and those who slander the chemical activities of this genial fungus are defaming a potential benefactor. Equally culpable are those who ignore them. If children were encouraged to cherish the same intelligent sympathy with yeast-cells which they so willingly display towards domestic animals and silkworms, perhaps there would be fewer crazy dervishes to deny us the moderate use of honest malt-liquors and unsophisticated wines, fewer pitiable maniacs to complicate our social problems by habitual excess.

Exactly how the cell accomplishes its great adventure remains a puzzle, but many parts of the machinery have already been recognised. Proceeding from the discovery of zymase (1897), with passing reference to the support thus given by Buchner to Liebig's view of fermentation, Chapman emphasises the importance of contributions to the subject by Harden and W. J. Young, first in revealing the dual nature of zymase and the distinctive properties of its co-enzyme (1904), next in recognising the acceleration and total increase in fermentation produced by phosphates, consequent on the formation of a hexosediphosphate (1908).

In this connection it will be remembered that a pentose-phosphate is common to the four nucleotides from which yeast nucleic acid is elaborated. The stimulating effect developed by phosphates would not be operative if the cell were not provided with an instrument for hydrolysing the hexose-diphosphate as produced, and this is believed by Harden to be supplied in the form of an enzyme, hexosephosphatase, the operation of which completes a cycle. As to the stages of disruption which precede the appearance of alcohol and carbon dioxide, that marked by pyruvic acid is the one which is now most favoured. The transformation of pyruvic acid into acetaldehyde and carbon dioxide under the influence of a carboxylase, followed by the hydrogenation of aldehyde to alcohol, is a more acceptable course than any alternative based upon lactic acid. Moreover, Fernbach and Schoen (1920) have confirmed their previous demonstration (1914) of pyruvic acid formation by yeast during alcoholic fermentation.

The strict definition of chemical tasks allotted to yeasts, moulds, and bacteria suggests an elaborate system of microbial trades-unionism. E. C. Grey (1918) found that *Bacillus coli communis* will, in presence of calcium carbonate, completely ferment forty times its own weight of glucose in forty-eight hours, and later (1920) exhibited the threefold character of the changes involved which produce (1) lactic acid, (2) alcohol with acetic and succinic acids, (3) formic acid, carbon dioxide, and hydrogen. Still more recent extension of this inquiry by Grey and E. G. Young (1921) has shown that the course of such changes will depend on the previous experience of the microbe. When its immediate past history is anærobic, fermentation under anærobic conditions yields very little or no lactic acid and greatly diminishes the production of succinic acid, whilst acetic acid appears in its place; admission of oxygen during fermentation increases the formation of lactic, acetic, and succinic acids, diminishes the formation of hydrogen, carbon dioxide, and formic acid, but leaves the quantity of alcohol unchanged. The well-known oxidising effect of *Aspergillus niger* has been shown by J. N. Currie (1917) to proceed in three stages marked by citric acid, oxalic acid, and carbon dioxide, whilst Wehmer (1918) has described the condition under which citric acid and, principally, fumaric acid are produced by *Aspergillus fumaricus*, a mould also requiring oxygen for its purpose. The lactic bacteria are a numerous family and resemble those producing acetic acid in their venerable record of service to mankind, whilst among the most interesting of the parvenus are those responsible for the conversion of starch into butyl alcohol and acetone. Although preceded by Schardinger (1905), who discovered the ability of B. *macerans* to produce acetone with acetic and formic acids, but does not appear to have pursued the matter further, the process associated with the name of A. Fernbach, and the various modifications which have been introduced during the past ten years are those best known in this country, primarily because of the anticipated connection with synthetic rubber, and latterly on account of the acetone famine arising from the War. The King's Lynn factory was resuscitated and arrangements had just been completed for adapting spirit distilleries to application of the process when, owing to the shortage of raw material in 1916, operations were transferred to Canada and ultimately attained great success in the factory of British Acetones, Toronto.

Much illuminating material is to be found in the literature of 1919-20 dealing with this question in its technological and bacteriological aspects. Ingenuity has been displayed in attempting to explain the chemical mechanism of the process, the net result of which is to produce roughly twice as much butyl alcohol as acetone. The fermentation itself is preceded by saccharification of the starch, and in this respect the bacteria resemble those moulds which have lately been brought into the technical operation of starch-conversion, especially in

France. The amyloclastic property of certain moulds has been known from very early times, but its application to spirit manufacture is of recent growth and underlies the amylo-process which substitutes *Mucor Boulard* for malt in effecting saccharification. Further improvement on this procedure is claimed for *B. mesentericus*, which acts with great rapidity on grain which has been soaked in dilute alkali; it has the advantage of inferior proteolytic effect, thus diminishing the waste of nitrogenous matter in the raw material.

Reviewing all these circumstances we find that, just as the ranks of trades-union labour comprise every kind of handicraftsman, the practitioners of micro-biochemistry are divisible into producers of hydrogen, carbon dioxide, formic acid, acetaldehyde, ethyl alcohol, acetic, oxalic, and fumaric acids, acetone, dihydroxyacetone, glycerol, pyruvic, lactic, succinic and citric acids, butyl alcohol, butyric acid. Exhibiting somewhat greater elasticity in respect of overlapping tasks, they nevertheless go on strike if underfed or dissatisfied with their conditions; on the other hand, with sufficient nourishment and an agreeable temperature, these micro-trades-unionists display the unusual merit of working for twenty-four hours a day. One thing, however, they have consistently refused to do. Following his comparison of natural and synthetic monosaccharides towards different families of yeast (1894), Fischer and others have attempted to beguile unsuspecting microbes into acceptance of molecules which do not harmonise with their own enzymic asymmetry. Various *apéritifs* have been administered by skilled *chefs de cuisine*, but hitherto the little fellows have remained obdurate.

Beyond a placid acceptance of the more obvious benefits of sunshine, the great majority of educated people have no real conception of the sun's contribution to their existence. What proportion of those who daily use the metropolitan system of tube-railways, for instance, could trace the connection between their progress and the sun? Very moderate instruction comprising the elements of chemistry and energy would enable most of us to apprehend this modern wonder, contemplation of which might help to alleviate the distresses and exasperation of the crush-hours.

For many years past, the problem connected with solar influence which has most intrigued the chemist is to unfold the mechanism enabling green plants to assimilate nitrogen and carbon. Although atmospheric nitrogen has long been recognised as the ultimate supply of that element from which phyto-protoplasm is constructed, modern investigation has indicated as necessary a stage involving association of combined nitrogen with the soil prior to absorption of nitrogen compounds by the roots, with or without bacterial cooperation. Concurrently, the agency by which green plants assimilate carbon is believed to be chlorophyll, operating under solar influence by some such mechanism as has been indicated in a preceding section.

Somewhat revolutionary views on these two points have lately been expressed by Benjamin Moore, and require the strictest examination, not merely owing to the fundamental importance of an accurate solution being reached, but also on account of the stimulating and engaging manner in which he presents the problem. Unusual psychological features have been introduced. Moore's 'Biochemistry,' published three months ago, will be read attentively by many chemists, but the clarity of presentation and the happy sense of conviction which pervade its pages must not be allowed to deter independent inquirers from confirming or modifying his conclusions. The book assumes a novel biochemical aspect by describing the life-history of a research. The first two chapters, written before the experiments were begun, suggest the conditions in which the birth of life may have occurred, whilst their successors describe experiments which were conducted as a test of the speculations and are already receiving critical attention from others (e.g., Baly, Heilbron and Barker, Transactions of the Chemical Society, 1921, p. 1025).

It is with these experiments that we are, at the moment, most concerned. The earliest were directed toward the synthesis of simple organic materials by a transformation of light energy under the influence of inorganic colloids, and indicated that formaldehyde is produced when carbon dioxide passes into uranium or ferric hydroxide sols exposed to sunlight or the mercury arc lamp. Moore then declares that, although since the days of de Saussure (1804) chlorophyll has been regarded as the fundamental agent in the photosynthesis of living matter, there is no experimental evidence that the primary agent may not be contained in the colourless part of the chloroplast, chlorophyll thus being the result of a later synthetic stage. 'The function of the chlorophyll may be a protective one to the chloroplast when exposed to light, it may be a light screen as has been suggested by Pringsheim, or it may be concerned in condensations and polymerisations subsequent to the first act of synthesis with production of formaldehyde' (p. 55). In this connection it is significant that chlorosis of green plants will follow a deficiency of iron even in presence of sunlight (Molisch, 1892), and that a development of chlorophyll can be restored by supplying this deficiency, although iron is not a component of the chlorophyll molecule; moreover, green leaves etiolated by darkness and then exposed to light regain their chlorophyll, which is therefore itself a product arising from photosynthesis.

H. Thiele (1907) recorded the swift conversion of nitrate into nitrite by the rays from a mercury quartz lamp, whilst O. Baudisch (1910) observed that daylight effects the same change, and from allied observations was led (1911) to conclude that assimilation of nitrate and nitrite by green plants is a photochemical process. Moore found (1918) that in solutions of nitrate undergoing this reduction green leaves check the accumulation of nitrite, indicating their capacity to

absorb the more active compound. Proceeding from the hypothesis that one of the organisms arising earliest in the course of evolution must have possessed, united in a single cell, the dual function of assimilating both carbon and nitrogen, he inquired (1918) whether the simplest unicellular algæ may not also have this power. He satisfied himself that in absence of all sources of nitrogen excepting atmospheric, and in presence of carbon dioxide, the unicellular algæ can fix nitrogen, grow and form proteins by transformation of light energy; the rate of growth is accelerated by the presence of nitrites or oxides of nitrogen, the latter being supplied in gaseous form by the atmosphere. From experiments (1919) with green seaweed (*Enteromorpha compressus*), Moore concluded also that marine algæ assimilate carbon from the bicarbonates of calcium and magnesium present in sea-water, which thereby increases in alkalinity, and further convinced himself that the only source of nitrogen available to such growth is the atmosphere. A description of these experiments, which were carried out in conjunction with E. Whitley and T. A. Webster, has appeared also in the Proceedings of the Royal Society (1920 and 1921).

For the purpose of distinguishing between (1) the obsolete view of a vital force disconnected with such forms of energy as are exhibited by non-living transformers and (2) the existence in living cells of only such energy forms as are encountered in non-living systems, Moore uses the expression 'biotic energy' to represent that form of energy peculiar to living matter. 'The conception, in brief, is that biotic energy is just as closely, and no more, related to the various forms of energy existing apart from life, as these are to one another, and that in presence of the proper and adapted energy transformer, the living cell, it is capable of being formed from or converted into various of these other forms of energy, the law of conservation of energy being obeyed in the process just as it would be if an exchange were taking place between any two or more of the inorganic forms' (p. 128). The most characteristic feature of biotic energy, distinguishing it from all other forms, is the power which it confers upon the specialised transformer to proliferate.

In 'The Salvaging of Civilisation,' H. G. Wells has lately directed the attention of thoughtful people to the imperative need of reconstructing our outlook on life. Convinced that the state-motive which, throughout history, has intensified the self-motive must be replaced by a world-motive if the whole fabric of civilisation is not to crumble in ruins, he endeavours to substitute for a League of Nations the conception of a World State. In the judgment of many quite benevolent critics his essay in abstract thought lacks practical value because it underestimates the combative selfishness of individuals. Try to disguise it as one may, this quality is the one which has enabled men to emerge from savagery, to build up that most wonderful system of colonial organisation, the Roman Empire, and to shake off the barbaric

lethargy which engulfed Europe in the centuries following the fall of Rome. The real problem is how to harness this combative selfishness. To eradicate it seems impossible, and it has never been difficult to find glaring examples of its insistence among the apostles of eradication. Why cry for the moon? Is it not wiser to recognise this quality as an inherent human characteristic, and whether we brand it as a vice or applaud it as a virtue endeavour to bend it to the elevation of mankind? For it could so be bent. Nature ignored or misunderstood is the enemy of man; nature studied and controlled is his friend. If the attacking force of this combative selfishness could be directed, not towards the perpetuation of quarrels between different races of mankind, but against nature, a limitless field for patience, industry, ingenuity, imagination, scholarship, aggressiveness, rivalry, and acquisitiveness would present itself; a field in which the disappointment of baffled effort would not need to seek revenge in the destruction of our fellow-creatures: a field in which the profit from successful enterprise would automatically spread through all the communities. Surely it is the nature-motive, as distinct from the state-motive or the world-motive, which alone can salvage civilisation.

Before long, as history counts time, dire necessity will have impelled mankind to some such course. Already the straws are giving their proverbial indication. The demand for wheat by increasing populations, the rapidly diminishing supplies of timber, the wasteful ravages of insect pests, the less obvious, but more insidious depredations of our microscopic enemies, and the blood-curdling fact that a day must dawn when the last ton of coal and the last gallon of oil have been consumed, are all circumstances which, at present recognised by a small number of individuals comprising the scientific community, must inevitably thrust themselves upon mankind collectively. In the campaign which then will follow, chemistry must occupy a prominent place because it is this branch of science which deals with matter more intimately than any other, revealing its properties, its transformations, its application to existing needs, and its response to new demands. Yet the majority of our people are denied the elements of chemistry in their training, and thus grow to manhood without the slightest real understanding of their bodily processes and composition, of the wizardry by which living things contribute to their nourishment and to their æsthetic enjoyment of life.

It should not be impossible to bring into the general scheme of secondary education a sufficiency of chemical, physical, mechanical, and biological principles to render every boy and girl of sixteen possessing average intelligence at least accessible to an explanation of modern discoveries. One fallacy of the present system is to assume that relative proficiency in the inorganic branch must be attained before approaching organic chemistry. From the standpoint of correlating scholastic knowledge with the common experiences and contacts of daily

life this is quite illogical; from baby's milk to grandpa's Glaxo the most important things are organic, excepting water. Food (meat, carbohydrate, fat), clothes (cotton, silk, linen, wool), and shelter (wood) are organic, and the symbols for carbon, hydrogen, oxygen and nitrogen can be made the basis of skeleton representations of many fundamental things which happen to us in our daily lives without first explaining their position in the periodic table of all the elements. The curse of mankind is not labour, but waste; misdirection of time, of material, of opportunity, of humanity.

Realisation of such an ideal would people the ordered communities with a public alive to the verities, as distinct from irrelevancies of life, and apprehensive of the ultimate danger with which civilization is threatened. It would inoculate that public with a germ of the nature-motive, producing a condition which would reflect itself ultimately upon those entrusted with government. It would provide the mental and sympathetic background upon which the future truthseeker must work, long before he is implored by a terrified and despairing people to provide them with food and energy. Finally, it would give an unsuspected meaning and an unimagined grace to a hundred commonplace experiences. The quivering glint of massed bluebells in broken sunshine, the joyous radiance of young beech-leaves against the stately cedar, the perfume of hawthorn in the twilight, the florid majesty of rhododendron, the fragrant simplicity of lilac; periodically gladden the most careless heart and the least reverent spirit; but to the chemist they breathe an added message, the assurance that a new season of refreshment has dawned upon the world, and that those delicate syntheses, into the mystery of which it is his happy privilege to penetrate, once again are working their inimitable miracles in the laboratory of the living organism.

EXPERIMENTAL GEOLOGY

By Dr. J. S. FLETT, F.R.S.

PRESIDENT OF THE GEOLOGICAL SECTION

AMONG the citizens of Edinburgh in the closing years of the eighteenth century there was a brilliant little group of scientific, literary, and philosophical writers. These were the men who founded the Royal Society of Edinburgh in the year 1783, and many of their important papers appear in the early volumes of its Transactions. Among them were Adam Ferguson, the historian and philosopher; Black, the chemist who discovered carbonic acid and the latent heat of water; Hope, who proved the expansion of water on cooling; Clerk of Eldin, who made valuable advances in the theory of naval tactics, and his brother, Sir George Clerk; Hutton, the founder of modern geology;

and Sir James Hall, the experimental geologist. These men were all intimate friends keenly interested in one another's researches. Quite the most notable member of this group was Hutton, who, not mainly for his eminence in geology, but principally for his social gifts, his bonhomie, and his versatility, was regarded as the centre of the circle. Hutton showed an extraordinary combination of qualities. His father was Town Clerk of Edinburgh. After starting as an apprentice to a Writer to the Signet, he took up the study of medicine at the Universities of Edinburgh and Paris, and graduated at Leyden. He then became a farmer on his father's property in Berwickshire, and also carried on chemical manufactures in Leith in partnership with Mr. Davie. He studied methods of agriculture in England and elsewhere, and was an active supporter of the movement for improving Scottish agriculture by introducing the best methods of other countries. A burning enthusiast in geology, especially in the 'theory of the earth,' he travelled extensively in Scotland, England, and on the Continent making geological observations.

His interests were not confined to geology, for he wrote a treatise on metaphysics, which seems to have been more highly esteemed in his day than in ours, and in his last years he produced a work on agriculture which was never published. The manuscript of this work is now in the library of the Edinburgh Geological Society. He also made interesting contributions to meteorology. Hutton's writings are as obscure and involved as his conversation was clear and persuasive, and it is only from the accounts of his friends, and especially Playfair's 'Life of Hutton,' that we can really ascertain what manner of man he was.

It could easily have happened that when Hutton died his unreadable writings might have passed out of notice, to be rediscovered at a subsequent time, when their value could be better appreciated. But Playfair's 'Explanations of the Hutton Theory,' as attractive and convincing still as when it was originally published, established at once the true position of Hutton as one of the founders of geology. Sir James Hall undertook a different task; he determined to put Hutton's theories to the test of experiment, and in so doing he became the virtual founder of modern experimental geology. It is my purpose in this address to show what were the problems that Hall attacked, by what methods he attempted to solve them, and what were his results. I shall also consider how far the progress of science has carried us since Hall's time regarding this department of geological science.

Hutton was a friend of Hall's father: they were proprietors of adjacent estates in the county of Berwick, and much interested in the improved practice of agriculture, and though the elder Hall (Sir John Hall of Dunglass) has apparently left no scientific writings, he was one of those who were familiar with Hutton's theories and a member of

the social group in which Hutton moved. Sir James Hall was the eldest son; born in 1761, he succeeded to the estate on his father's death in 1776. Educated first at Cambridge and then at Edinburgh University, at an early age he became fascinated by Hutton's personality, though repelled by his theories. He tells us how for three years he argued with Hutton daily, rejecting his principles. Hutton prevailed in the long run, and Sir James Hall was convinced. Hall's objection to Hutton's theories is not difficult to understand, though he has not himself explained it. The world was sick of discussions on cosmogony in which rival theorists appealed to well-known facts as proof of the most extravagant speculations. Serious-minded men were losing interest in these proceedings. The Geological Society of London was founded in 1807, and one of its objects is stated to be the avoidance of speculation and the patient accumulation of facts. No doubt Hall also was greatly influenced by the discoveries that Black and Hope had made by pure experimental investigation. His bent of mind was towards chemical, physical, and experimental work, while Hutton was not only a geologist but also a metaphysician.

Foreign travel was then an essential part of the education of a Scottish gentleman, and the connection between France, Holland, and Scotland was closer than it is today. Hall travelled widely; in his travels two subjects seem to have especially engrossed him. One was architecture, on which he wrote a treatise which was published in 1813 and is now forgotten. The other was geology. He visited the Alps, Italy, and Sicily. In Switzerland he may have met De Saussure and discussed with him the most recent theories of their time regarding metamorphism and the origin of granites, schists, and gneisses. In Italy and Sicily one of his objects was to observe the phenomena of active volcanoes, and to put to the test of facts the theories of Werner and of the Scottish school regarding the origin of basalt, whinstone, trap, and the older volcanic rocks of the earth's crust. At Vesuvius he made his famous observation of the dykes that rise nearly vertically through the crater wall of Somma, which he held to prove the ascent of molten magma from below through fissures to the surface. This was in opposition to the interpretation of the Wernerians, who regarded them as filled from above by aqueous sediments, and Hall's conclusions, which were strikingly novel at the time, have been abundantly confirmed.

We obtain a pleasant glimpse of Hall's life in Berwickshire in the account of his visit with Hutton and Playfair to Siccar Point in the year 1788. The start was made from Dunglass, where probably the party had spent the night. The great conglomerates of the Upper Old Red Sandstone of that district had much impressed Hutton. He saw in them the evidence of new worlds built out of the ruins of the old, with no sign of a beginning and no prospect of an end—a thesis which

was one of the corner-stones of his 'Theory of the Earth.' No doubt Hall knew or suspected that in the cliff-exposures at Siccar Point, where the Old Red rests upon the Silurian, there was evidence which would put this dogma to a critical test.

Hall's first experiments were begun in the year 1790, his object being to ascertain whether crystallisation would take place in a molten lava which was allowed to cool slowly. It was generally believed that the results of fusion of rocks and earths were in all cases vitreous, but glassmakers knew that if glass was very slowly cooled, as sometimes happened when a glass furnace burst, the whole mass assumed a stony appearance. An instance of this had come under Hall's notice in a glassworks in Leith, and its application to geology was clear. Hutton taught that even such highly crystalline rocks as granite had been completely fused at the time of their injection, and their coarse crystallisation was mainly due to slow cooling.

For the purpose of his experiments Hall selected certain whinstones of the neighborhood of Edinburgh, such as the dolerites of the Dean, Salisbury Crags, Edinburgh Castle, the summit of Arthur's Seat, and Duddingston; but he also used lava from Vesuvius, Etna, and Iceland. He made choice of graphite crucibles, and conducted his experiments in the reverberatory furnace of an ironfoundry belonging to Mr. Barker. As had been shown by Spallanzani, to whose experiments Hall does not refer, lavas are easily fusible under these conditions. Hall had no difficulty in melting the whinstones and obtaining completely glassy products by rapid cooling. He now proceeded to crystallise the glass by melting it again, transferring it from the furnace to a large open fire, where it was kept surrounded by burning coals for many hours, and thereafter very slowly cooled by allowing the fire to die out. He succeeded in obtaining a stony mass in which crystals of felspar and other minerals could be clearly seen. Some of his specimens were considered to be very similar in appearance to the dolerites on which his experiments were made.

The only means of measuring furnace temperatures available at that time were the pyrometers which had recently been invented by Wedgwood. Hall found that a temperature of 28 to 30 Wedgwood yielded satisfactory results. This seems to be about the melting-point of copper, approximately 1000° C.

Whether by design or accident, Hall chose for his experiments precisely the rocks which were most suitable for his purpose. If granite had been selected no definite results would have been obtained. De Saussure had already made fusion experiments on granite. Ninety years afterwards the problem was completely solved by Fouqué and Lévy, who used a gas furnace and a nitrogen thermometer. They found that it was possible to obtain either porphyritic or ophitic structure by modifying the conditions, and that the minerals had exactly

the characters of those of the igneous rocks. Some of Hall's recrystallised dolerites were examined microscopically by Fouqué and Lévy, and, as might be expected, they proved to be only partly crystallised, showing skeleton crystals of olivine and felspar with grains of iron ore in a glassy base.

Some curious observations made by Hall in his experimental work were also confirmed by Fouqué and Lévy. The crystalline whinstones were more difficult to melt than the glasses which were obtained from them, and the glass crystallised best when kept for a time at a temperature a little above its softening point. It is not possible to assign a definite melting-point to the Scottish whinstones with which Hall worked. Many of them contain zeolites, which fuse readily. Minerals are also present that decompose on heating, such as calcite, dolomite, chlorite, and serpentine. The whole process is very complex, and probably takes place by several stages not sharply distinct. Similarly the glasses cannot be said to have a melting-point. They are really super-cooled liquids. A full explanation of what took place in Hall's crucibles cannot be given at the present day, but there is no room for doubt that his experiments were good and his inferences accurate. His friend Kennedy, who had recently discovered the presence of alkalis in igneous rocks, furnished valuable support to Hall's conclusions by showing that the chemical composition of whinstone and of basalt were substantially identical.

Apparently the results of Hall's work were not received with unmixed approbation. Hutton was distinctly uneasy, and it has been suggested that he feared if experimental work turned out unsuccessful it might bring his theories into discredit. The Wernerians frankly scoffed; they preferred argument to experiment, and the endless discussion went on. Gregory Watt repeated Hall's experiments by fusing Clee Hill dolerite, a hundredweight or two at a time, in a blast-furnace. But there can be no doubt that among those who were not already committed to the principles of Werner the new evidence produced a strong impression, and helped to widen the circle of Hutton's supporters.

Hall's most famous experiments were on the effect of heat combined with pressure on carbonate of lime. The problem was, Can powdered chalk be converted into firm limestone or into marble by heating it in a confined space? In this case Hutton's theories were in apparent conflict with experimental facts; from general observations he held it proved that heat and pressure had consolidated limestones and converted them into marbles. It was well known, of course, that limestone, when heated in an open vessel, was transformed into quicklime, and Black had shown that the explanation was that carbonic acid had been expelled in the form of gas.

The experiments were begun in 1790, but deferred till 1798 after

Hutton's death. Hutton quite openly disapproved of experiments. His famous apophthegm has often been quoted about those who 'judge of the great operations of the mineral kingdom by kindling a fire and looking in the bottom of a crucible.' In deference to the feelings of his master and his father's friend, Sir James Hall, with admirable self-restraint, decided not to undertake experimental investigations in opposition to Hutton's expressed opinion. With a few month's interruption in 1800 they were continued till 1805. A preliminary account of the results was communicated to the Royal Society of Edinburgh on August 30, 1804, and the final papers submitted on June 3, 1805. Hall states that he made over 500 individual experiments and destroyed vast numbers of gun-barrels in this research.

The method adopted was to use a muffle-furnace burning coal or coke and built of brick. No blast seems to have been employed. The chalk-powder was enclosed in a gun-barrel cut off near the touch-hole and welded into a firm mass of iron. The other end of the barrel could be kept cool by applying wet cloths, and as it was not in the furnace its temperature was always comparatively low. Various methods of plugging the barrel were adopted; at first he used clay, sometimes with powdered flint. Subsequently a fusible metal which melted at a temperature below that of boiling water was almost always preferred. Borax glass with sand was used in some of the experiments, but it was liable to cracking when allowed to cool, and consequently was not always gas-tight. It was essential, of course, that in sealing up the gun-barrel, and in subsequently removing the plug, the temperatures should never be so high as to have any sensible effect on the powdered chalk or limestone. Hall tried vessels with screwed stoppers or lids at first, but never found them satisfactory.

In the gun-barrel there was always a certain amount of air enclosed with the chalk. Very early in the experiments it was shown that if no air-space was provided the fusible metal burst the barrel. No means was found to measure the size of the air-space accurately, but approximately it was equal to that of the powdered chalk used in the experiment. If the air-space was too large, or if there was an escape of gas, part of the chalk was converted into lime.

As each experiment lasted several hours the temperature of the chalk was approximately equal to that of the part of the muffle in which it was placed. Pyrometry was as yet in its infancy. Wedgwood had invented pyrometric cones and Hall had heard of them, but apparently at first he was not in possession of a set. He made his own cones as nearly similar as possible to those of Wedgwood, and subsequently obtaining a set of Wedgwood's cones he standardized his own by comparison with them. His gun-barrels of Swedish and Russian iron ('Old Sable') were softened, but seldom gave way except when the internal pressures were of a high order. Some of the gun-barrels seem to have

been used for many experiments without failure occurring. As Hall made his own pyrometric cones, and we have no details of their composition and the method of preparation, it is not possible to do more than guess at the temperatures to which his powdered lime and chalk were exposed. There is no doubt that by constant practice and careful observation he was able to regulate the temperature within fairly wide limits.

Hall began his experiments as already stated in 1798. They were interrupted for about a year (March 1800 to March 1801), and on March 31, 1801, he had obtained a considerable measure of success. A charge of forty grains of powdered chalk was converted into a firm granular crystalline mass of limestone. The loss on weighing was approximately 10 per cent. Another charge of eighty grains was converted into marble (on March 3, 1801), with a loss of approximately 5 per cent., and the crystalline mass showed distinct rhombohedral cleavage.

Though it cannot be said that his success was easily won he was by no means satisfied, and for another four years he continued his researches. Many different methods were tried in order to ascertain the most satisfactory and reliable; his ambition was to attain complete control of the process so that he could always be certain of the result. Porcelain tubes were tried, which he obtained from Wedgwood. They were very liable, however, to allow escape of the gases through pores. Many different methods of obtaining gas-tight stoppers were experimented on, but he does not seem to have found anything really better than the fusible metal. A slight loss of weight in the chalk used seemed inevitable, and the amount of loss varied irregularly; after long trials he ultimately succeeded in reducing this to less than one per cent. Various kinds of carbonate of lime were used, including chalk, limestone, powdered spar, oyster shells, periwinkles, and each of these was crystallised in turn. Many experiments showed that a reaction might take place between the chalk powder and the glass of the tube in which it was contained. The result was a white deposit often crystalline, and a certain amount of uncombined carbonic acid gas which escaped when the tube was opened. No doubt the white mineral was wollastonite. Hall proved that it was a silicate of lime which dissolved in acid and left a cloud of gelatinous silica. Thereafter he used platinum vessels instead of glass to contain the charge of carbonate of lime which he wanted to fuse. The effect of impurities in the material used was also investigated. Critics had urged that his limestone was not pure. Hall aptly replied that this was so much the better; natural limestones were seldom pure, and his point was that limestone might be fused under heat and pressure. He obtained the purest precipitated carbonate of lime, and used also perfectly transparent crystalline spar; the results were, as we might expect, that the pure substances and the fairly coarse

crystalline powder were more difficult to fuse than the very finely ground natural chalk. These results show that Hall had very complete control of his experimental processes, and that even small differences in fusibility did not escape his observation.

As natural limestones are always moist, Hall's attention was next directed to the influence of water on the crystallisation of his powders. This added greatly to the difficulty of the experiments, but by wonderful skill he succeeded in using a few grains of water (apparently up to five per cent. of the weight of the chalk). The result was to improve the crystallisation, for the reason, as Hall believed, that the pressure was increased. He noticed at the same time that hydrogen was produced, which took fire when the gun-barrel was discharged. Probably there was also some carbonic oxide. About this time he was using bars of Russian iron into which a long cylindrical cavity had been bored. He then tried other volatile ingredients such as nitrate of ammona, carbonate of ammonia, and gunpowder. In January 1804 he was able to convert chalk into firm limestone at a temperature about 960° (melting-point of silver) in presence of small quantities of water with a loss of less than one-thousandth part of the chalk used.

Finally he attempted to measure the pressure which was necessary to effect re-crystallisation under the conditions of his experiments. No pressure gauges were available at that date, and after many trials he employed a stopper faced with leather and forced against the mouth of his iron tube by means of weights acting either directly or through a lever. He ultimately succeeded in obtaining gas-tight junctions under pressures ranging from 52 up to 270 atmospheres, and concluded that 52 atmospheres was the least pressure which could be satisfactory. This is equal to the pressure of a column of water 1,700 feet high or to a column of rock 700 feet high. A 'complete marble' was formed at a pressure of 86 atmospheres and carbonate of lime 'absolutely fused' under a pressure of 173 atmospheres.

In reviewing these classic experiments after a lapse of 120 years we feel that there are many points on which we should have liked more detailed information. One essential, for example, is exact chemical analysis of all the materials employed. Even chalk is variable in composition to a by no means negligible extent. Oyster shells and periwinkle shells contain organic matter, which would account for the considerable loss in weight they always exhibited. The use of glass tubes was a defect in the early experiments afterwards remedied by employing platinum vessels. Although in all the experiments the charge was weighed it seems clear that at first at any rate the materials were not carefully dried. In the experiments with water it was seldom possible to provide absolutely against the escape of moisture when the fusible metal was introduced. Most of all we may regret the inadequate means of measuring the temperatures at which the experiments were

conducted. The measurements of pressure were made by the simplest possible means, and it was only by great experimental skill and care that even approximate results could be obtained.

Such criticisms, however, do not mar the magnificent success of Hall's experiments. For nearly a hundred years, in spite of the advance of physical and chemical science, no substantial improvement on his results was attained. His work was immediately recognized as trustworthy and conclusive, and became a classic in the literature of experimental geology. Although not exactly the founder of this school of research, for Spallanzani and De Saussure had made fusion experiments on rocks before his time, he placed the subject in a prominent position among the departments of geological investigation, and did great service in supporting Hutton's theories by evidence of a new and unexpected character.

SOME PROBLEMS IN EVOLUTION

By Professor EDWIN S. GOODRICH, F.R.S.

PRESIDENT OF THE ZOOLOGICAL SECTION

IN all probability factors of inheritance exist, and the fundamental problem of biology is how are the factors of an organism changed, or how does it acquire new factors? In spite of its vast importance, it must be confessed that little advance has been made towards the solution of this problem since the time of Darwin, who considered that variation must ultimately be due to the action of the environment. This conclusion is inevitable, since any closed system will reach a state of equilibrium and continue unchanged, unless affected from without. To say that mutations are due to the mixture or reshuffling of pre-existing factors is merely to push the problem a step farther back, for we must still account for their origin and diversity. The same objection applies to the suggestion that the complex of factors alters by the loss of certain of them. To account for the progressive change in the course of evolution of the factors of inheritance and for the building up of the complex it must be supposed that from time to time new factors have been added; it must further be supposed that new substances have entered into the cycle of metabolism, and have been permanently incorporated as self-propagating ingredients entering into lasting relation with pre-existing factors. We are well aware that living protoplasm contains molecules of large size and extraordinary complexity, and that it may be urged that by their combination in different ways, or by the mere regrouping of the atoms within them, an almost infinite number of changes may result, more than sufficient to account for the mutations which appear. But this does not account for the building up of the original complex. If it must

be admitted that such a building process once occurred, what right have we to suppose that it ceased at a certain period? We are driven, then, to the conclusion that in the course of evolution new material has been swept from the banks into the stream of germ-plasm.

If one may be allowed to speculate still further, may it not be supposed that factors differ in their stability?—that whereas the more stable are merely bent, so to speak, in this or that direction by the environment, and are capable of returning to their original condition, as a gyroscope may return to its former position when pressure is removed, other less stable factors may be permanently distorted, may have their metabolism permanently altered, may take up new substance from the vortex, without at the same time upsetting the system of delicate adjustments whereby the organism keeps alive? In some such way we imagine factorial changes to be brought about and mutations to result.

Let it not be thought for a moment that this admission that factors are alterable opens the door to a Lamarckian interpretation of evolution! According to the Lamarckian doctrine, at all events in its modern form, a character would be inherited after the removal of the stimulus which called it forth in the parent. Now of course, a response once made, a character once formed, may persist for longer or shorter time according as it is stable or not; but that it should continue to be produced when the conditions necessary for its production are no longer present is unthinkable. It may, however, be said that this is to misrepresent the doctrine, and that what is really meant is that the response may so react on and alter the factor as to render it capable of producing the new character under the old conditions. But is this interpretation any more credible than the first?

Let us return to the possible alteration of factors by the environment. Unfortunately there is little evidence as yet on this point. In the course of breeding experiments the occurrence of mutations has repeatedly been observed, but what led to their appearance seems never to have been so clearly established as to satisfy exacting critics. Quite lately, however, Professor M. F. Guyer, of Wisconsin, has brought forward a most interesting case of the apparent alteration at will of a factor or set of factors under definite well-controlled conditions.[7] You will remember that if a tissue substance, blood-serum for instance, of one animal be injected into the circulation of another, this second individual will tend to react by producing an anti-body in its blood to antagonise or neutralise the effect of the foreign serum. Now Professor Guyer's ingenious experiments and results may be briefly summarised as follows. By repeatedly injecting a fowl with the substance of the lens of the eye of a rabbit he obtained anti-lens serum. On injecting this 'sensitised' serum into a pregnant female rabbit it

[7] *American Naturalist*, vol. lv. 1921; *Jour. of Exper. Zoology*, vol. xxxi. 1920.

was found that, while the mother's eyes remained apparently unaffected, some of her offspring developed defective lenses. The defects varied from a slight abnormality to almost complete disappearance. No defects appeared in untreated controls, no defects appeared with non-sensitised sera. On breeding the defective offspring for many generations these defects were found to be inherited, even to tend to increase and to appear more often. When a defective rabbit is crossed with a normal one the defect seems to behave as a Mendelian recessive character, the first generation having normal eyes and the defect reappearing in the second. Further, Professor Guyer claims to have shown that the defect may be inherited through the male as well as the female parent, and is not due to the direct transmission of anti-lens from mother to embryo *in utero*.

If these remarkable results are verified, it is clear that an environmental stimulus, the anti-lens substance, will have been proved to affect not only the development of the lens in the embryo, but also the corresponding factors in the germ-cells of that embryo; and that it causes, by originating some destructive process, a lasting transmissible effect giving rise to a heritable mutation.

Professor Guyer, however, goes farther, and argues that, since a rabbit can also produce anti-lens when injected with lens substance, and since individual animals can even produce anti-bodies when treated with their own tissues, therefore the products of the tissues of an individual may permanently affect the factors carried by its own germ-cells. Moreover he asks, pointing to the well-known stimulative action of internal secretions (hormones and the like), if destructive bodies can be produced, why not constructive bodies also? And so he would have us adopt a sort of modern version of Darwin's theory of Pangenesis, and a Lamarckian view of evolutionary change.

But surely there is a wide difference between such a poisonous or destructive action as he describes and any constructive process. The latter must entail, as I tried to show above, the drawing of new substances into the metabolic vortex. Internal secretions are themselves but characters, products (perhaps of the nature of ferments behaving as environmental conditions, not as self-propagating factors, moulding the responses, but not permanently altering the fundamental structure and composition of the factors of inheritance.

Moreover, the early fossil vertebrates had, in fact, lenses neither larger nor smaller on the average than those of the present day. If destructive anti-lens had been continually produced and had acted, its effect would have been cumulative. A constructive substance must, then, have also been continually produced to counteract it. Such a theory might perhaps be defended; but would it bring us any nearer to the solution of the problem?

The real weakness of the theory is that it does not escape from the fundamental objections we have already put forward as fatal to

Lamarckism. If an effect has been produced, either the supposed constructive substance was present from the first, as an ordinary internal environmental condition necessary for the normal development of the character, or it must have been introduced from without by the application of a new stimulus. The same objection does not apply to the destructive effect. No one doubts that if a factor could be destroyed by a hot needle or picked out with fine forceps the effects of the operation would persist throughout subsequent generations.

Nevertheless, these results are of the greatest interest and importance, and, if corroborated, will mark an epoch in the study of heredity, being apparently the first successful attempt to deal experimentally with a particular factor or set of factors in the germ-plasm.

There remains another question we must try to answer before we close, namely, 'What share has the mind taken in evolution?' From the point of view of the biologist, describing and generalising on what he can observe, evolution may be represented as a series of metabolic changes in living matter moulded by the environment. It will naturally be objected that such a description of life and its manifestations as a physico-chemical mechanism takes no account of mind. Surely, it will be said, mind must have affected the course of evolution, and may indeed be considered as the most important factor in the process. Now, without in the least wishing to deny the importance of the mind, I would maintain that there is no justification for the belief that it has acted or could act as something guiding or interfering with the course of metabolism. This is not the place to enter into a philosophical discussion on the ultimate nature of our experience and its contents, nor would I be competent to do so; nevertheless, a scientific explanation of evolution cannot ignore the problem of mind if it is to satisfy the average man.

Let me put the matter as briefly as possible at the risk of seeming somewhat dogmatic. It will be admitted that all the manifestations of living organisms depend, as mentioned above, on series of physico-chemical changes continuing without break, each step determining that which follows; also that the so-called general laws of physics and of chemistry hold good in living processes. Since, so far as living processes are known and understood, they can be fully explained in accordance with these laws, there is no need and no justification for calling in the help of any special vital force or other directive influence to account for them. Such crude vitalistic theories are now discredited, but tend to return in a more subtle form as the doctrine of the interaction of body and mind, of the influence of the mind on the activities of the body. But, try as we may, we cannot conceive how a physical process can be interrupted or supplemented by non-physical agencies. Rather do we believe that to the continuous physico-chemical series of events there corresponds a continuous series of mental events inevitably connected with it; that the two series are but partial views

or abstractions, two aspects of some more complete whole, the one seen from without, the other from within, the one observed, the other felt. One is capable of being described in scientific language as a consistent series of events in an outside world, the other is ascertained by introspection, and is describable as a series of mental events in psychical terms. There is no possibility of the one affecting or controlling the other, since they are not independent of each other. Indissolubly connected, any change in the one is necessarily accompanied by a corresponding change in the other. The mind is not a product of metabolism as materialism would imply, still less an epiphenomenon or meaningless by-product as some have held. I am well aware that the view just put forward is rejected by many philosophers, nevertheless it seems to me to be the best and indeed the only working hypothesis the biologist can use in the present state of knowledge. The student of biology, however, is not concerned with the building up of systems of philosophy, though he should realise that the mental series of events lies outside the sphere of natural science.

The question, then, which is the more important in evolution, the mental or the physical series, has no meaning, since one cannot happen without the other. The two have evolved together *pari passu.* We know of no mind apart from body, and have no right to assume that metabolic processes can occur without corresponding mental processes, however simple they may be.

Simple response to stimulus is the basis of all behaviour. Responses may be linked together in chains, each acting as a stimulus to start the next; they can be modified by other simultaneous responses, or by the effects left behind by previous responses, and so may be built up into the most complicated behaviour. But owing to our very incomplete knowledge of the physico-chemical events concerned, we constantly, when describing the behaviour of living organisms, pass, so to speak, from the physical to the mental series, filling up the gaps in our knowledge of the one from the other. We thus complete our description of behaviour in terms of mental processes we know only in ourselves (such as feeling, emotion, will) but infer from external evidence to take place in other animals.

In describing a simple reflex action, for instance, the physico-chemical chain of events may appear to be so completely known that the corresponding mental events are usually not mentioned at all, their existence may even be denied. On the contrary, when describing complex behaviour when impulses from external or internal stimuli modify each other before the final result is translated into action, it is the intervening physico-chemical processes which are unknown and perhaps ignored, and the action is said to be voluntary or prompted by emotion or the will.

The point I wish to make, however, is that the actions and behaviour of organisms are responses, are characters in the sense de-

scribed in the earlier part of this address. They are inherited, they vary, they are selected, and evolve like other characters. The distinction so often drawn by psychologists between instinctive behaviour said to be inherited and intelligent behaviour said to be acquired is as misleading and as little justified in this case as in that of structural characters. Time will not allow me to develop this point of view, but I will only mention that instinctive behaviour is carried out by a mechanism developed under the influence of stimuli, chiefly internal, which are constantly present in the normal environmental conditions, while intelligent behaviour depends on responses called forth by stimuli which may or may not be present. Hence, the former is, but the latter may or may not be inherited. As in other cases, the distinction lies in the factors and conditions which produce the results. Instinctive and intelligent behaviour are usually, perhaps always, combined, and one is not more primitive or lower than the other.

It would be a mistake to think that these problems concerning factors and environment, heredity and evolution, are merely matters of academic interest. Knowledge is power, and in the long run it is always the most abstruse researches that yield the most practical results. Already, in the effort to keep up and increase our supply of food, in the constant fight against disease, in education, and in the progress of civilisation generally, we are beginning to appreciate the value of knowledge pursued for its own sake. Could we acquire the power to control and alter at will the factors of inheritance in domesticated animals and plants, and even in man himself, such vast results might be achieved that the past triumphs of the science would fade into insignificance.

Zoology is not merely a descriptive and observational science, it is also an experimental science. For its proper study and the practical training of students and teachers alike, well-equipped modern laboratories are necessary. Moreover, if there is to be a useful and progressive school contributing to the advance of the science, ample means must be given for research in all its branches. Life doubtless arose in the sea, and in the attempt to solve most of the great problems of biology the greatest advances have generally been made by the study of the lower marine organisms. It would be a thousand pities, therefore, if Edinburgh did not avail itself of its fortunate position to offer to the student opportunities for the practical study of marine zoology.

In his autobiography, Darwin complains of the lack of facilities for practical work—the same need is felt at the present time. He would doubtless have been gratified to see the provision made since his day and the excellent use to which it has been put; but what seems adequate to one generation becomes insufficient for the next. We earnestly hope that any appeal that may be made for funds to improve this department of zoology may meet with the generous response it certainly deserves.

APPLIED GEOGRAPHY

By Dr. D. G. HOGARTH, C.M.G.

PRESIDENT OF THE GEOGRAPHICAL SECTION

THE term which I have taken for the title of my address has been in use for some years as a general designation of lendings or borrowings of geographical results, whether by a geographer who applies the material of his own science to another, or by a geologist or a meteorologist, or again an ethnologist or historian, who borrows of the geographer. Whether geography makes the loan of her own motion or not, the interest in view, as it seems to me, is primarily that, not of geography, but of another science or study. The open question whether that interest will be served better if the actual application be made by the geographer or by the other scientist or student does not concern us now.

Such applications are of the highest interest and value as studies, and, still more, as means of education. As studies, not merely are they links between sciences, but they tend to become new subjects of research, and to develop with time into independent sciences. As means of education they are used more generally, and prove themselves of higher potency than the pure sciences from which or to which, respectively, the loans are effected. But, in my view, geography, thus applied, passes, in the process of application, into a foreign province and under another control. It is most proper, as well as most profitable, for a geographer to work in that foreign field; but, while he stays in it, he is, in military parlance, seconded.

Logical as this view may appear, and often as, in fact, it has been stated or implied by others (for example, by one at least of my predecessors in this chair, Sir Charles Close, who delivered his presidential address to the section at the Portsmouth Meeting in 1911), it does not square with some conceptions of geography put forward by high authorities of recent years. These represent differently the status of some of the studies, into which, as I maintain, geography enters as a subordinate and secondary element. In particular, there is a school, represented in this country and more strongly in America, which claims for geography what, in my view, is an historical or ethnological or even psychological study, using geographical data towards the solution of problems in its own field; and some even consider this not merely a function of true geography, but its principal function now and for the future. Their 'new geography' is and is to be the study of 'human response to land-forms.' This is an extreme American statement; but the same idea is instinct in such utterances, more sober and guarded, as that of a great geographer, Dr. H. R. Mill, to the effect that the

ultimate problem of geography is 'the demonstrative and quantitative proof of the control exercised by the Earth's crust on the mental processes of its inhabitants. Dr. Mill is too profound a man of science not to guard himself, by that saving word 'ultimate,' from such retorts as Professor Ellsworth Huntington, of Yale, has offered to the extreme American statement. If, the latter argued, geography is actually the study of the human response to land-forms, then, as a science it is in its infancy, or, rather, it has returned to a second childhood; for it has hardly begun to collect exact data to this particular end, or to treat them statistically, or to apply to them the methods of isolation that exact science demands. In this country geographers are less inclined to interpret 'new geography' on such revolutionary lines; but one suspects a tendency towards the American view in both their principles and their practice—in their choice of lines of inquiry or research and their choice of subjects for education. The concentration on man, which characterizes geographical teaching in the University of London, and the almost exclusive attention paid to Economic Geography in the geographical curricula of some other British Universities make in that direction. In educational practice, this bias does good, rather than harm, if the geographer bears in mind that Geography proper has only one function to perform in regard to man—namely, to investigate, account for, and state his distribution over terrestrial space—and that this function cannot be performed to any good purpose except upon a basis of Physical Geography—that is, on knowledge of the disposition and relation of the Earth's physical features, so far as ascertained to date. To deal with the effect of man's distribution on his mental processes or political and economic action is to deal with him geographically indeed, but by applications of geography to psychology, to history, to sociology, to ethnology, to economics, for the ends of these sciences; though the interests of geography may be, and often are, well served in the process by reflection of light on its own problems of distribution. If in instruction, as distinct from research, the geographer, realising that, when he introduces these subjects to his pupils, he will be teaching them not geography, but another science with the help of geography, insists on their having been grounded previously or elsewhere in what he is to apply—namely, the facts of physical distribution—all will be well. The application will be a sound step forward in education, more potent perhaps for training general intelligence than the teaching of pure geography at the earlier stage, because making a wider and more compelling appeal to imaginative interest and pointing the adolescent mind to a more complicated field of thought. But if geography is applied to instruction in other sciences without the recipients having learned what it is in itself, then all will be wrong. The teacher will talk a language not under-

stood, and the value of what he is applying cannot be appreciated by the pupils.

If I leave this argument there for the moment, it is with the intention of returning to it before I end today. It goes to the root, as it seems to me, of the unsatisfactory nature of much geographical insruction given at present in our islands. The actual policy of the English Board of Education seems to contemplate that geography should be taught to secondary students, only in connection with history. If this policy were realised in instructional practice by encouragement or compulsion of secondary students to undergo courses of geography proper, with a view to promotion subsequently to classes in historical geography (*i. e.*, if history be treated geographically by application of another science previously studied), it would be sound. But I gather from Sir Halford Mackinder's recent report that such is not the practice. Courses in geography proper are not encouraged during the secondary period of education at all. Encouragement ceases with the primary period, at an age before which only the most elementary instruction in such a science can be assimilated—when, indeed, not much more can be expected of pupils than the memorising of those summary diagrammatic expressions of geographical results, which are maps. How these results have been arrived at, what sort of causes account for physical distribution, how multifarious are its facts and features which maps cannot express even on the minutest scale—these things must be instilled into minds more robust than those of children under fourteen; and until some adequate idea of them has been imbibed it is little use to teach history geographically. So, at least, this matter seems to me.

It will be patent enough by now that I am maintaining geography proper to be the study of the spatial distribution of all physical features on the surface of this earth. My view is, of course, neither novel nor rare. Almost all who of late years have discussed the scope of geography have agreed that distribution is of its essence. Among the most recent exponents of that view have been two directors of the Oxford School, Sir Halford Mackinder and Professor Herbertson. When, however, I add that the study of distribution, rightly understood, is the whole essential function of geography, I part company from the theory of some of my predecessors and contemporaries, and the practice of more. But our divergence will be found to be not serious; for not only do I mean a great deal by the study of distribution—quite enough for the function of any one science!—but I claim for geography to the exclusion of any other science all study of spatial distribution on the earth's surface. This study has been its well recognised function ever since a science of that name has come to be restricted to the features of the terrestrial surface—that is, ever since 'geography' in the eighteenth century had to abandon to its child geo-

logy the study of what lies below that surface even as earlier it had abandoned the study of the firmament to an elder child, astronomy. Though geography has borne other children since, who have grown to independent scientific life, none of these has robbed her of that one immemorial function. On the contrary, they call upon her to exercise it still on their behalf.

Let no one suppose that I mean by this study and this function merely what Professor Herbertson so indignantly repudiated for an adequate content of his science—physiography *plus* descriptive topography. Geography includes these things, of course, but she embraces also all investigation both of the actual distribution of the earth's superficial features and of the causes of the distribution, the last a profound and intricate subject towards the solution of which she has to summon assistance from many other sciences and studies. She includes, further, in her field, for the accurate statement of actual distribution, all the processes of survey—a highly specialised function to the due performance of which other sciences again lend indispensable aid; and, also, for the diagrammatic presentation of synthetised results for practical use, the equally highly specialised processes of cartography. That seems to me an ample field, with more than sufficient variety of expert functions, for any one science. And I have not taken into account either the part geography has to play in aiding other sciences, as they aid her, by application of her data, or, again, certain investigations of terrestrial phenomena, at present incumbent upon her, because special sciences to deal with them have not yet been developed—or, at least, fully developed—although their ultimate growth to independence can be foreseen or has already gone far. Such, for the moment, are geodetic investigations, in this country at any rate. In Germany, I understand, geodesy has attained already the status of a distinct specialism. Here the child has hardly separate existence. But beyond a doubt it will part from its parent, even as oceanography has parted. Indeed some day, in a future far too distant to be foreseen now, many, or most, of the investigations which now occupy the chief attention of geographical researchers may cease to be necessary. A time must come when the actual distribution of all phenomena on the earth's surface will have been ascertained, and all the relief upon it and every superficial feature which cartography can possibly express in its diagrammatic way will have been set out finally on the map. That moment, however, will not be the end of geography as a science, for there will still remain the investigation of the causes of distribution, the scientific statement of its facts, and the application of these to other sciences. Let us not, however, worry about any ultimate restriction of the functions of our science. The discovery and correlation of all the facts of geographical distribution and their final presentation in diagram-

matic form are not much more imminent than the exhaustion of the material of any other science!

In the meantime, for a wholly indeterminate interval, let us see to it that all means of investigating the phenomena of spatial distribution on the earth be promoted, without discouragement of this or that tentative means as unscientific. The exploration of the terrestrial surface should be appreciated as a process of many necessary stages graduated from ignorance up to perfect knowledge. It is to the credit of the Royal Geographical Society that it has always encouraged tentative, and, if you like, unscientific first efforts of exploration, especially in parts of the world where, if every prospect pleases, man is very vile. Unscientific explorations are often the only possible means to the beginning of knowledge. Where an ordinary compass cannot be used except at instant risk of death it is worth while to push in a succession of explorers unequipped with any scientific knowledge or apparatus at all, not merely to gain what few geographical data untrained eyes may see and uneducated memories retain, but to open a road on which ultimately a scientific explorer may hope to pass and work, because the local population has grown, by intercourse with his unscientific precursors, less hostile and more indifferent to his prying activities. There seems to me now and then to be too much criticism of Columbus. If he thought America was India he had none the less found America.

I have claimed for the geographer's proper field the study of the causation of distribution. I am aware that this claim has been, and is denied to geography by some students of the sciences which he necessarily calls to his help. But if a science is to be denied access to the fields of other sciences except it take service under them, what science shall be saved? I admit, however, that some disputes can hardly be avoided, where respective boundaries are not yet well delimited. Better delimitation is called for in the interest of geography, because lack of definition, causing doubts and questions about her scope, confuses the distinction between the science and its application. The doubts are not really symptoms of anything wrong with geography, but, since they may suggest to the popular mind that in fact something is wrong, they can be causes of disease. Their constant genesis is to be found in the history of a science, whose scope has not always been the same, but has contracted during the course of ages in certain directions while expanding in others. If, in the third century B. C., Eratosthenes had been asked what he meant by geography, he would have replied, the science of all the physical environment of man whether above, upon, or below the surface of the earth, as well as of man himself as a physical entity. He would have claimed for its field what lies between the farthest star and the heart of our globe, and the nature and relation of everything composing the universe. Geography, in fact, was then not only the whole of natural science, as we understand the term, but also

everything to which another term, ethnology, might now be stretched at its very widest.

Look forward now across two thousand years to the end of the eighteenth century A. D. Geography has long become a mother. She has conceived and borne astronomy, chemistry, botany, zoology, and many more children, of whom about the youngest is geology. They have all existences separate from her and stand on their own feet, but they preserve a filial connection with her and depend still on their mother science for a certain common service, while taking off her hands other services she once performed. Restricting the scope of her activities, they have set her free to develop new ones. In doing this she will conceive again and again and bear yet other children during the century to follow—meteorology, climatology, oceanography, ethnology, anthropology and more. Again, and still more narrowly, this new brood will limit the mother's scope; but ever and ever fecund, she will find fresh activities in the vast field of earth knowledge, and once and again conceive anew. The latest child that she has borne and seen stand erect is, as I have said, geodesy; and she has not done with conceiving.

Ever losing sections of her original field and functions, ever adding new sections to them, geography can hardly help suggesting doubts to others and even to herself. There must always be a certain indefiniteness about a field on whose edges fresh specialisms are for ever developing toward a point at which they will break away to grow alone into new sciences. The mother holds on awhile to the child, sharing its activities, loth to let go, perhaps even a little jealous of its growing independence. It has not been easy to say at any given moment where geography's functions have ended and those of, say, geology or ethnology have begun. Moreover, it is inevitably asked about this fissiparous science from which function after function has detached itself to lead life apart—what, if the process continues, as it shows every sign of doing, will be left to geography later or sooner? Will it not be split up among divers specialisms, and become in time a venerable memory? It is a natural, perhaps a necessary, question. But what is wholly unnecessary is that any answer should be returned which implies a doubt that geography has a field of research and study essentially hers yesterday, to-day, and to-morrow; still less which implies any suspicion that because of her constant parturition of specialisms geography is, or is likely in any future that can be foreseen, to be moribund.

SCIENTIFIC IDEALISM[1]

By Dr. WILLIAM E. RITTER
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IDEALISM is dead—at least many people think so. And no small number of those who think thus are persons of humane sentiments withal, and hold their belief under compulsion rather than willingly. They believe the evidence compels them to accept this view, whether it be agreeable to them or not. How else, they reason, can the course of events of these later decades be interpreted?

The history of man is the story of the terribly brutal reality of his existence on earth and his efforts to escape from this reality into some ideal realm wherein the peace and happiness and joy occasionally experienced in life shall be perfected and endure forever.

So powerful has been the allurement of this ideal realm that many of our race in ages past have devoted their best power, sometimes even their very lives to exploiting it and devising ways and means by which all may finally reach this promised land. These rare ones are acclaimed great among men and accepted as teachers and leaders just because they express the common longings of mankind, of the lowly as well as of the great.

In all the ages and culture stages of the past imaginarily perfect conditions of life have been among the most compelling motives with humanity. These imaginings have been near the heart of all the great religions and all the great philosophies of the world, their culmination as philosophy having been, probably, the several forms of idealism of the eighteenth and early nineteenth centuries. But what has come of it all?

If the realism of these questioners is of the dramatic sort, the answer they give to their own question is likely to be brief and laconic. A few dozen words and a gesture will tell the story: Germany and Austro-Hungary in August, 1914, and again in October, 1918! Russia in August, 1914, in April, 1917, in November, 1918, and today! Treaty making in Versailles in 1919! The human misery of all Europe during the war years and up to the present moment! The astounding transformations that have occurred in the hearts and lives of our own people since the new era opened! Finally, the uncertainty, the fore-

[1] President's address at the Berkeley Meeting of the Pacific Division, American Association for the Advancement of Science, August 4-7, 1921.

boding, the background of distrust, hatred, and fear with which all the peoples of the earth look toward the future!

Surely there is ground enough for the supposition that realism, a realism as stupid and brutal as Satan himself could rejoice in, has at last established its full claims—that idealism has departed from the earth wholly and for all time.

And what, they ask, has contributed more to these results than science? Have not scientific discovery and invention based on such discovery so involved man in a network of material forces and mechanical devices that he can hardly satisfy a single need, gratify a single desire, form a single idea, or think a single thought without the permission of this tyranny of material things?

For a modern seriously to attempt to live traditional idealism for one day could result only in death or something worse before the setting of the sun.

Nor is this the worst that science has done. In these grosser matters the injury to idealism has consisted only in thrusting the sensible realities of nature more numerously, more variedly and more insistently than ever before into the problem of living from hour to hour and day to day.

Of graver concern, science has, we are told to remember, entered the very domain of philosophy and besieged the citadel of idealism itself. Even the strongholds of morality and religion are not spared by the advance of realistic science. Copernican astronomy, Lavoisian chemistry, Lyellian geology and Darwinian biology have united in constructing so solid a foundation for a realistic philosophy of all life that the time-honored super-structure of idealistic philosophy is doomed to collapse and ruin.

The fact is thrown into our faces by the acceptors of the view that science is implacably hostile to idealism, that in these last years, not satisfied with its imminent victory over theoretic idealism, it has entered into full alliance with the ancient powers of darkness and malignity to accomplish the destruction of idealism itself and of all that idealism has created in the world.

High power explosives with guns and tanks and dreadnaughts and submarines and aircraft to make them effective went far toward realizing this ambition, but the finishing stroke is poison gases. The abundance of raw material for their manufacture, the ease of their transportation, the secrecy with which their nature and manufacture can be surrounded and, finally, the large co-efficient of deadliness of the best of them, make them very promising as means for completing the business of destroying all the works of civilized races, if not the races themselves. Of course no people, not even the scientists whose

devotion to research discovers the gases, intended to use these upon *themselves*. The enemy alone are to be destroyed. But since the enemy can, if also scientifically civilized, discover poison gases too, the result, whether consciously aimed at or not—the destruction of all idealism and its fruits—is certain.

But is this picture of the state of things really true? Is science indeed so destructive an enemy to idealism?

I deny it. Never, I affirm, has science been purposely hostile to idealism. Never has it designed to act against idealism. In so far as science has injured idealism it has done so undesignedly and unwittingly. Science has gone on its way, single-minded, bent only on ever increasing man's store of natural knowledge, on penetrating ever farther into the depths of natural truth.

But denial that the harm done by science to idealism has been intentional is of little consequence. What I chiefly care about is not the blamelessness of science for its injury to idealism. I would set forth the true relation of science to idealism and the moral obligation which this relation forces upon science. My aim is to acknowledge the terrible error committed by science in holding, even by implication, that it knows nothing about morals and has no moral obligations, and to show something of the nature of its obligation.

Speaking in broad terms, what I want to point out is that once science gives serious attention to the question of its own relation to idealism and realism it recognizes that the first question to be decided is not that of idealism vs. realism, not that of idealism or no idealism, nor of realism or no realism. Rather it is the question of what in essence idealism is, and what realism is.

To push this inquiry to exhaustiveness would need days. We seem stopped on the threshold by the demand for a treatise while all we can have is a tract. But it is not wholly so. From its very office as a ministrant to the common life of mankind, science can, if true to herself, concentrate her elaborate, forbidding treatises into simple, dramatic, appealing tracts at the urgent need of humanity.

It is in response to the danger call of civilization that I seek to reduce to the dimensions of a tract, the laborious findings of science on the real nature of the conflict between humanity's longings, beliefs, hopes and faiths and those forces—grim, powerful and ever alert—which oppose their attainment.

Notice, in the first place, the kinship of science with our ordinary intelligence. Nobody doubts that every item of our matter-of-fact knowledge about the universe in which we live is anything else than part and parcel of our general store of knowledge. Surely what the housewife knows about the things of her home; what

the workman knows about his tools and materials; what the merchant knows about his goods; what the engineer knows about the structure, the plans and the materials of which it is made; what the physician knows about our bodily members in health and disease, are but parts of common knowledge. But the articles that so much concern the housewife, the workman, the merchant, the engineer, the physician are the very same that concern the scientist. The only difference is that they concern the housewife, workman, engineer and physician more immediately, more vitally than they do the scientist. So the scientist, being perforce also domestic, workman, merchant and so on, is less apt to contend that his special knowledge is wholy different in kind from the knowledge of work-a-day men and women. None have cherished the characterization of science as organized common sense more than have scientists.

But again, has anybody ever doubted that mental structures in the form of memories, guesses, views and ideas enter essentially and largely into the intelligent pursuit of all callings? Planning the next meal, the next house-cleaning, the next jacket for baby; visualizing more effective wrenches and augurs and knives; imagining hats and shoes and gowns more appealing to customers, are part of the very life of the successful housekeeper, mechanic, merchant. Just so it is as to essential mental procedure with the scientific investigator. Apart from something mentally pictured but not yet realized—apart from some hypothesis—scientific discovery is unthinkable. Would any scientist claim that science is less dependent on ideas than is housekeeping, blacksmithing or merchandizing?

But having ideas is never the whole story in any department of rational human living. Everywhere and always the mental picture, the idea is something aimed at, something needed or desired for the fulfilment or completion or rounding out of some still larger, more inclusive need or desire. Whether the adage "Nothing existeth to itself alone" be strictly true or not, it certainly is true as to ideas. It is as much the nature of ideas to be in relation with one another and with other things as it is for them to exist at all. It is from this inter-relatedness, this mutual dependence of ideas and their relation to the individual's life as a whole that they get whatever drive and potency they have. But ideas plus the valuations placed upon them and the impulsions to act connected with them are exactly the things to which common experience has given the name ideals. Ideals are ideas in action or ready for action toward some supposedly good end.

From this it is seen that the scientist, especially the investigator, is of necessity an idealist by the same token by which the ordinary individual is an idealist. His idealism differs from that of other men only

as his technical knowledge differs from their common knowledge; namely, in that he uses his technical knowledge differently from the way practical men use their common knowledge. The outcome of this is the perception that science is not only idealistic but that its idealism marks the very summit of true, that is natural, idealism.

The idealism of Christian theology and last century's speculative philosophy are pseudo-idealism. They are disembodied idealism. They are mythical or dramaturgic idealism. If consequently, they have been stripped of some of their power it is only false power that has been taken from them and they have suffered only as thousands upon thousands of other products of man's imagination have suffered when it breaks away from its naturalistic setting and its control by the totality of human life.

If science is so beneficent in aim, how comes it that in spite of its gigantic prevalence in our day, that day fraught though it be with calamity and human misery perhaps as terrible as any of all the ages past, is yet heavy with borebodings of still greater calamity? Manifestly something has stood in the way, is standing in the way of man's becoming the beneficiary of this, surely one of the most notable and unique of all his creations.

Is it possible that man should bring into existence so mighty a thing, so potentially beneficent a thing as science and yet fail to reap its benefits; indeed, should allow it to become a powerful ally of forces working to his ruin?

Astounding though the truth may be, an open-minded reading of the story of man's career on earth reveals that he has *always been doing just that sort of thing!* Human history furnishes no guarantee that man will use any good thing, even of his own creating, to his own full and lasting benefit.

In all the stages of human culture from the lowest savagery to the highest civilization men demonstrate their ability to employ their highest spiritual powers as well as their lowest physical powers to their own harm, even to their destruction. Religion, art, learning, philanthropy no less than appetite, sex and material wealth—man has time and again made to contribute to his own undoing. This is a truth the perception of which is greatly important. But of still greater importance is the perception of another closely related truth, namely that with civilized man it lies ever within the range of his intelligence to choose that course of action which will make him a continuous beneficiary of anything his intelligence enables him to produce. In its very nature intelligence is able to prevent its own creations from being harmful. Of course man will never choose that which he is certain will do him more harm than good. It is only as to probabilities of harm and good, or greater and lesser good, or greater and lesser harm, that his choosing so often goes amiss.

To gain an understanding of these wonderful paradoxes of human nature would require a treatise. Sufficient to say that it is possible to go far toward such an understanding if we start with a mind wide open to the idea of man's kindred with the rest of living nature, particularly with the rest of animal nature, and go through to the end vigorously and unflinchingly. For myself, I am convinced that western civilization has come at last to a situation where nothing short of an unqualifiedly and carefully worked out *system of natural ethics will secure its continued progress; indeed, will save it from deterioration and final decay.*

Ours is a day for great and fateful decisions. Mighty goals of objective reality and mighty possibilities of action must be chosen among.

Neither optimism nor pessimism but that confidence which the wisely informed can alone possess is now, as never before, the way of salvation.

Let me outline what seems to me the most important part scientists must play in developing such an ethics as has just been mentioned and making the vital choices presented by the situation. The first thing for them to do is to accept unfalteringly and insist upon the necessity that all others shall accept, the *facts*, all of them, without addition or subtraction, which the system of nature, including human nature presents. The haggling that has gone on among the learned of the western world for two thousand years over the question of whether nature revealed through our senses is the ultimate reality or an illusion of one sort or another, must be and I believe is in a fair way to be brought to an end before long. Nevertheless it is astonishing, once one's attention is fixed on the point, how prevalent still even among men of science is the ancient state of uncertainty about the value of facts, and the still more ancient custom of furbishing them up in hundreds of ways to suit preadopted ideas and ideals. Many an excellent scientist still speaks of the laws of nature as though they were quite apart from and above the facts of nature. To such scientists laws are the essence of truth while facts are without much dignity, being mere objects of sense. Beyond a few such vital facts as the body's need for air, water and solid food, it seems that many scientists, in common with millions of the unscientific, still conceive themselves privileged to select such facts as interest them and to ignore all such as do not interest them. Uncritical a priorism still flourishes mightily in one form or another in the home of science. These marks of immaturity of science produce, under the stress of modern conditions, sundry untoward consequences. For one thing a new kind of criticism of science has been growing up in very recent years. The old conflict which theology forced upon science during the early centuries of the intellectual rejuvenation of Europe virtually ended about fifty years ago with science triumphant.

This new criticism which science is encountering is sociological and ethical rather than theological. The essense of the criticism is that science is not regardful of, indeed is largely inimical to, the spiritual welfare of man. This results, it is charged, from the avowed materialistic and mechanistic character of science. For one I frankly admit that there is much justice in this criticism, but I believe close scrutiny of the situation will discern that the real grounds of it are less in the fact that science is materialistic and mechanistic than that it *belittles what is greatest and best in human nature, especially in human personality.*

What is the defect within the body of science that makes it open to such criticism?

For several decades past there has been great controversy within the domain of the biological sciences over the relative merit of mechanism and vitalism. This controversy is largely academic, and consequently shows no signs of reaching a conclusion. The solution will come, I am quite sure, through the emergence of the problem from the realm of pure theory into that of practical life. The form which the inquiry assumes when it comes into the realm of human actuality is this: Accepting the patent fact that man is so wonderfully machine-like that he may be called a machine, at least provisionally, the question arises in what sense a machine? Would he be a machine in the sense of mathematical mechanics or in some other sense? The theory that he is a machine after the manner of mathematical mechanics disposes of itself quickly and completely the moment it submits to the test of practicability. Nothing is more distinctive of manufactured machines than that they can be standardized. All the individual machines of a particular kind can be so constructed that all the parts are interchangeable. Wheel for wheel, shaft for shaft, lever for lever, plate for plate, bolt for bolt—they are cast, often literally, in the same mold. To the last detail it matters not at all which piece goes into which machine. And note what is implied in the expression the "assembling" of manufactured machines—*pre*design and independent fabrication are implied.

These marks set off the manufactured machine so sharply from the human machine, if we decide it may so be called, that no one, not even the most dogmatic bio-mechanist, would deny the facts. Several other equally important differences could be pointed out, but may be omitted for brevity's sake. If men, actual men, are to be called machines, the term must have a sharply different meaning from what it has to the manufacturer. What shall this different meaning be? How shall it be arrived at?

Nothing stands out more unequivocally in the natural history of the human species, particularly of those portions of it that have made notable advances in culture, than that such advances have been due pri-

marily to a very few individuals who are called great because of their special capacities. The fact is never denied. All progress is initiated by the great warrior, the great political organizer, the great poet, the great philosopher, the great explorer, the great inventor, the great physician, the great teacher—one or a very few of each kind for each nation. Except for these rare ones there would be little or no cultural progress, little or no civilization. The fact, I say, is not in question. Even when due allowance is made for the pressure, external and internal, of general need, the importance and rôle of which I do not for a moment minimize, that pressure seems sure to come largely to naught unless the exceptional individual arises to lead and guide the latent forces. Only when it comes to interpreting the facts is there question. Of course one who is committed to the dogma that natural law in the sense of unvarying regularity, of perfect evenness of procedure, is the essence of natural truth, while facts are only sensory, is bound to find some way to avoid accepting these great *personalities* as truly significant so far as the general scheme of things is concerned. They must be reduced to "nothing buts" somehow, when a universal view is sought. They are to be regarded as accidents or by-products in the operation of central forces or of environmental pressure according to the last decade's biological orthodoxy. Or according to this decade's biological orthodoxy they are mere somatic variants, wholly independent of the germ plasm and consequently meaningless so far as the real part of organic matter is concerned. It is admitted that such exceptional personalities have cut some figure in the past career of man. For the future, with the improvement of the germ plasm under eugenic guidance, their role will become less and less until finally there will be reached the far-off state of absolute uniformity in an excellence which formerly would have been called divine.

The logically ideal human goal of the mechanistic philosophy is that all men shall be standardized after the manner of automobiles, on a model that is eugenically perfect. Man, germinally perfected, according to this philosophy would be standardized on the level, say of Packard limousines. Fords, Chevrolets, Essexes—small, cheap, and worst of all, different, would be eliminated.

Pray do not miss the main point here. You can hardly fail to see that it concerns the moral bearings of the mechanistic philosophy. But particular moral qualities and criteria of right and wrong are not my present subject. My point is rather to show that the dead-levelness of that philosophy has no room for such conception as right and wrong at all. The basal question is: Could there be such a thing as virtue if there were nothing but virtue, or if virtue were one only and that one wholly devoid of gradation? The mechanistic philosophy of life implies a solution of the problem of good and evil by eliminating difference.

This brings me to the place were I can indicate the direction in which the solution lies of biology's controversey over mechanism and vitalism. The cue is given by the demand of nature herself that personality shall be accepted and respected. Common sense surely finds no difficulty in heeding this demand, nor can it object to calling man a machine if some way of designating the machine shall be adopted which recognizes the obvious difference between the human and any inanimate machine whatsoever. And no designation, thus discriminative, could be more satisfactory than the simple word "living" prefixed to the word machine when the human or any other kind of animal is referred to. If the difference between a living man and the same man dead be accepted at face value, I am quite sure all sensible persons would willingly recognize men as machines—would even be willing to be called machines themselves.

The practical objection to the mechanical philosophy of life is that because it has no place in its scheme for the person it really has no place for life itself. A non-living thing is more real and hence more significant than a living one to this philosophy. A dead horse would be as valuable as a live one to the mechanistic philosopher who should stick to his philosophy in his practical life.

For brevity's sake I am going to assume that in any imaginable real world of real men, women and children, difference both in kind and degree is as indispensable to virtue as is food or anything else without which life could not exist. And here our reflections reach far beyond the mechanical philosophy, for we cut square across the main axis of ethical theory that has dominated European thought for many centuries, that theory hinging on belief in the ultimate good, necessarily one and alone because without a rival, as the proper goal of human striving.

There is now general agreement, I believe, among those who work practically as contrasted with those who discourse abstractedly on moral problems, that one cannot rightly assess or wisely promote a particular good until he knows what evil lurks within or behind it. Nor can he effectively combat a particular evil until he knows what good is mingled with it. These things I assume without argument, for I must leave a little time in which to show how diversity of talent and virtue, even to the greatest genius, though irreconcilable with a rigorously mechanistic philosophy of human life, is perfectly reconcilable with a naturalistic philosophy conceived in accordance with the best traditions of the natural history sciences.

Let me be very objective. Systematic botany and zoology have long been the type of natural history or the natural sciences. In common practice they have been placed over against the physical sciences on the one hand and the humanistic sciences on the other. Fixing attention more on subject matter than on knowledge corresponding to it, we see at once that nothing sets the plant and animal worlds off from the

inanimate world more obtrusively than the enormous number and diversity of kinds in the former as contrasted with those in the latter. Then comparing the plant and animal world with the human world we see that nothing stands out more sharply than the diversity of individuals in the human world as contrasted with that in the plant and animal worlds. The point is brought home with great force by noticing that each individual in the human world has a name all to itself whereas very little of this occurs in either of the other worlds. But the exceptions are highly significant. A few of the higher animals, notably those most closely associated with man, do have names. Speaking broadly, the human world presents itself to our understanding as composed of *individuals* and the plant and animal worlds as composed of *species*, while the inanimate world, sharply contrasted with both, stands in our knowledge as composed of a comparatively few kinds of *mass* and *energy*. The continents of the earth appear as land masses and the seas as bodies of water. Cloud masses bring rain, and coal and oil deposits and mountain streams furnish power. The point to be kept in the foreground is the indubitable fact that all solid advance in science has done as much to validate *diversity* in nature as it has to validate *uniformity*. It may be said with strict truthfulness, I think, that science rests just as much on laws of diversity as it does on laws of uniformity. There is no justification, psychological, logical or of any other sort for the common assumption that the essence of scientific knowledge is uniformity alone. Surely we cannot affirm that there could be scientific or any other knowledge without uniformity in nature. But equally surely, we cannot affirm that there could be scientific or any other knowledge without diversity in nature.

Of the many chapters in the history of science that could be drawn upon for proof of the conclusions just stated time will permit the notice of but one. But that one is epochal and crucial.

I refer to the fact that variety—difference—in living nature had to be *taken*, as though a thing of free grace, by Darwin for the very foundation of his theory of descent. And I call attention to this vital truth: Darwin and all the ablest naturalists since his time have devoted some of their best powers of observation and of thought to the problem of organic variety and variation, the one unqualifiedly positive result of which has been to widen and deepen the recognized fact of such diversity. Almost endless has been the controversy over the *casual explanation* of variation; but over the *fact of it*, no controversy at all. So it happens that when the naturalist passes from the world of plants and of animals to that of man, preserving the mental attitude and using the general method which his whole career has made second nature to him, he finds the individuality and personality so distinctive of the new realm readily conformable to his disciplinary predilection, his mental and manual technique, and his conceptual scheme.

One fact, however, though by no means new to him, stands out with such boldness in the new realm as to make him ply his methods of treating diversity with more assiduity and thoughtfulness than ever before. That fact is this very one of personality. The material with which he deals in the human realm compels him to notice attentively that the separateness and independence of human beings are not only quantitative and numerical but are qualitative as well. They are not only isolated and thus individual but they are differently individual. Every human being is not merely an *other*, relative to all the rest, but it is a *different* other.

I call special attention to the fact that *otherness* and *qualitatively different otherness* are very distinct conceptions, and I insist on the importance of the distinction, so vitally does it concern practical human affairs. Recognition of this distinction would be promoted by adopting distinctive terms for the two. There should be a general term for mere numerical otherness and another term for qualitatively different otherness. In my own usage I have come to make the two terms *individuality* and *personality* serve these ends. Latterly for me an individual man, woman, child, is only an *other* man, woman, child; while a personal man, woman, or child is not only an *other* but a different other. The full significance of thus distinguishing individuality from personality is seen only when we consider it as pertaining to the social and ethical realms.

In order rightly to exhibit it in these realms it is necessary to refer to still another aspect of the evolution theory, that is the adaptive character of living things. That man is dependent upon adaptation to his environment, as are all other organisms, is now so much a truism that the general fact only needs referring to as a preliminary to mentioning an aspect of the broad problem which has not yet got a sufficiently secure and influential place either in common knowledge or science. That men, like all other organisms must be adapted to their surroundings is so obvious that no one questions it. But recognizing that adaptation is essential in *certain aspects* of life and in the relation of life to certain aspects of environment, is quite a different thing from recognizing that *every aspect* of life whatever, is adaptive to environment, environment being considered broadly enough.

Beginning in modern times with the astronomy of Copernicus and Galileo the whole march of physical science onward to this very day with its discoveries like those of the Curies and Michelson, have been toward a commanding outlook from which may be seen the unity of all inanimate nature. Similarly the march of biological science has been toward a commanding outlook from which the unity of living nature is in clear sight. All this has brought it to pass that an adequate interpretation of man's relation to nature cannot be reached by

taking man and environment each piece-meal, with many of the pieces quite ignored even at that.

Nothing less than human nature in its entirety will suffice for the basis of modern interpretation of man's relation to nature. Consequently when that relation is expressed in the terms of adaptation and environment each must be generalized. Every aspect of human life, spiritual as well as physical, must be recognized as adaptively related to some of the aspects of the system of nature as a whole in its role as environment of human life. Not positive kowledge alone, but art, fine as well as industrial, philosophy, and religion, are manifestations of man's effort to solve the problem of his existence upon earth. They are all partly means and partly ends in the struggle for existence, this familiar and much abused phrase being rightly understood.

And now for the main point in connection with the idea of adaptation. I have just referred to the abused phrase "struggle for existence." One aspect of the abuse of it is in applying it everywhere and at all times but without any analytical definition of it. It is constantly used with its most general meaning but rarely so applied to any special instance. Yet a little reflection brings to light the glaring inadequacy of such usage. Does any one suppose that the struggle of a tree for existence is the same kind of struggle as that of a fish or a bird or a man? Is anything more obvious than that what a sea anemone does in struggling for existence is quite different from what a lion does? All manner of sophistical argument can, I am aware, be produced to justify common practice in this matter. But the facts of the situation are so obvious that for the unsophisticated these arguments do not need reviewing or answering. Manifestly the principle according to which the idea of struggle in living nature must be applied if it is to correspond to the facts and to be really useful, must be expressed about as follows: *The general phrase, struggle for existence, is meaningless for any particular plant or animal except as the struggle is for the existence of that plant or animal, according to its particular kind.*

A tree struggles for a tree's existence not for a fish's or a bird's or a man's existence; and furthermore in each case for some particular kind of tree or fish or man. An oak's struggle is different from a pine's struggle; a Fijian's struggle is different from a Parisian's, and so on through the whole gamut of life, past, present and future.

Let us bring this principle home with all its inherent force. To this end we fix attention upon that portion of the animal realm to which we ourselves belong; namely the portion equipped with highly developed muscular and nervous systems and body members for making these systems effective. Nothing is more obvious even to commonsense zoology than that the part of animal creation thus equipped falls naturally into two main divisions. There are brute animals and there are

human animals. And what differences between brutes and humans are the most striking? There are at least two which stand out so conspicuously that even a child notices them. These are first, the upright posture of the human being, by which his hands are freed from the locomotor function and made available for all sorts of activities in obedience to intelligence; and second, the language mode of expression of the human animal. To be sure, neither of these separates the human from the brute absolutely. If they did they would be quite out of harmony with the principles which prevail everywhere in natural history and so would be far less significant. Many brute animals do assume the upright posture to some degree and use their fore limbs for other purposes than moving about; and many of them surely express themselves to some extent in ways which can be properly designated as language. But the fullness of development of each of these attributes in the human as contrasted with its development in any of the brutes is such that no one ever fails to distinguish the lowest living human from the highest living brute. When we come to scrutinize closely these two differences, the free hands and language—we find the bipedal form and habit of the human as contrasted with the quadrupedal form and habit of the brute and likewise the linguistic power of the human as contrasted with the brute are both inseparably connected with the fact that the activities of brutes are predominantly hereditary; that is, are performed according to plans and methods passed along from parents to offspring in the same way that plans of physical organs and parts are passed along. On the other hand, with humans we find the activities not predominantly hereditary. That is to say, they are not inborn but have to be acquired, learned afresh by each individual. We express this difference by calling the activities of brutes mainly instinctive and those of humans mainly rational and intelligent. Brute animal activity is largely instinct while human animal activity is largely on the basis of intelligence and reason.

When civilized man is reached in the evolutional scale the eons old struggle for existence takes the form of the struggle of mankind for and on the basis of ideas and ideals. These ideas and ideals are natural by the same token that sensations, reflex actions and instincts are natural—that token being that all alike belong in deepest essence to the very nature of man.

About the most convincing sign that an attribute of any living being is natural is its adaptability. An attribute's adaptiveness is that by virtue of which it contributes to the fitness of the being to live in the surroundings in which its life is set.

The fact of natural origin—origin by birth and growth—and of natural adaptiveness imply that adaptation is never absolutely perfect, hence forever needs improvement, is forever open to progress. It is demonstrated by observations on the activities of brute animals and

of primitive men as they live in nature that the imperfection of adaptiveness to conditions of life under purely sensory and reflexive activity is very serious. In fact it is so serious that great injury, even great destruction comes to individual and race because of it. Indeed I believe it demonstrable that had not nature found a way of correcting the injurious activities to which purely instinctive behavior is ever liable, progress in animal evolution would have ended in such classes as insects and reptiles. But to find such correctives is a part of the very essence of organic origin and growth.

The great correctives found by nature are what we call reason and intelligence, essential elements in which are *Ideas* and *Ideals*. According to common conception ideas have their seat in the human brain, while ideals are seated first and foremost in the human heart.

This sketch of the part Science is playing and still more must play in the herculean task of producing a system of natural ethics, is now finished. But before leaving it I will try to compact into the limits of a last minute, the substance of what has been said.

Brute animal life became transformed into human animal life through the countless millenniums of struggle of all life to fit itself ever more completely to the conditions which make any life at all possible.

Victory, under the name humanity, finally crowned the struggle when and because of, the slow and painful acquisition by the coming victor of the power to wage the struggle on the basis of ideas and ideals instead of on the ancient basis of the purely hereditary, that is instinctive activity of his brute ancestors.

This new and higher form of the struggle as it occurs within and among the members of the human species gives what in broadest generality we name the Moral Law. And so it is that Moral Law is Natural Law, Natural Law in its application to man being the totality of the impulsions, the efforts, and the acts, by which mankind strives to attain its own highest good by making itself ever better fitted for living, whether in this or in any other world that may be its abode.

FIELD CROP YIELDS IN NEW JERSEY FROM 1876 TO 1919

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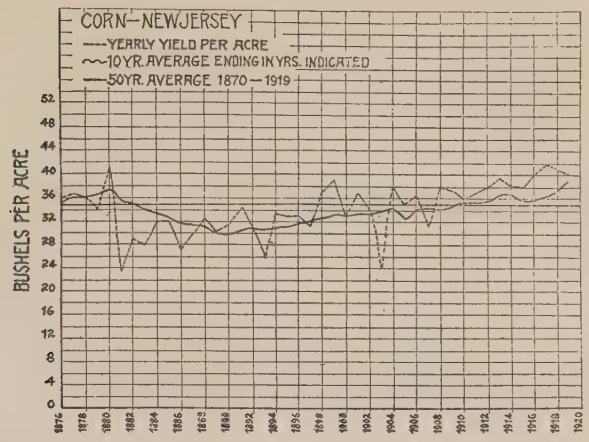
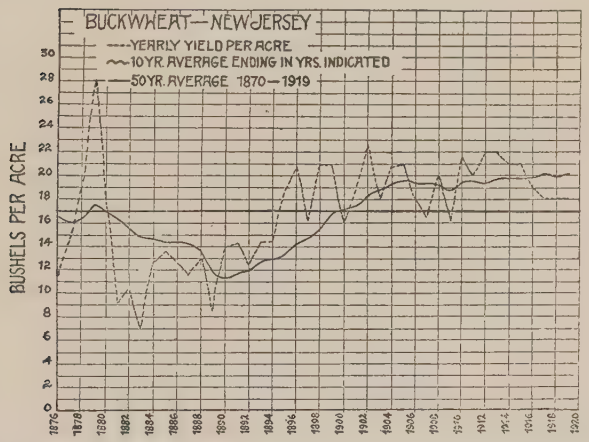
WHILE New Jersey, on account of its extensive trucking areas, its peach and apple orchards, its plantations of small fruits, etc., is generally known as the "Garden State," as a matter of fact about 75 per cent. of its agricultural acreage is devoted to the growing of corn, wheat, rye, oats, buckwheat, potatoes, sweet potatoes and hay. In spite of its varied and intensive manufacturing interests and its growing suburban territory, its farms produced in 1920 over 11,000,000 bushels of corn, 1,500,000 bushels of wheat, over 1,000,000 bushels of rye, almost 3,000,000 bushels of oats, 2,000,000 bushels of sweet potatoes, almost 15,000,000 bushels of white potatoes and 545,000 tons of hay. It is entirely with these crops that the present paper deals, particularly with their average yields per acre from 1876 to 1919. A study of the yields over such a length of time should indicate at least in part either agricultural progression or retrogression and should afford some evidence as to the value and results of agricultural teachings over that period.

Of the factors controlling yields, climate undoubtedly is the most important and by climate is meant sunlight, the presence or absence of which influences the amounts of sugars, starches, fats, proteins, etc.; temperature, which influences germination, growth and in part the activities of soil bacteria and moisture or rainfall which determines the activities of soil bacteria and hence the availability of plant food. Only occasionally are all of the elements making up climate favorable for the plant over its entire period of growth and when this happens we have as a rule maximum yields and bumper crops. Climate as a whole can not be regulated, although by irrigation rainfall can be supplemented. By the selection of hardy species of plants some climatic effects can be overcome and by mulches, evaporation and therefore loss of heat from the soil can be reduced. For the most part however yields are at the mercy of climate.

Another important factor entering into yields and one which is controllable to a certain point is the fertility of the soil. The natural fertility can be added to by the use of commercial fertilizers and farm




BUCKWHEAT—NEW JERSEY
—YEARLY YIELD PER ACRE
~10 YR. AVERAGE ENDING IN YRS. INDICATED
—50 YR. AVERAGE 1870—1919
BUSHELS PER ACRE

and green manures. The soil itself can be improved by the use of green and animal manures for the purpose of increasing the amount of vegetable matter and therefore its water holding power and bacterial activities. Increasing the yielding power by the addition of fertilizers is of course possible only up to the point where the law of diminishing returns starts to operate and other limiting factors are extra labor and material costs which must be considered together with the prices received for farm products.

Still another element is crop rotation. A good rotation favors high yields by utilizing plant food more evenly, by conserving moisture and regulating humus and by the prevention of rapid losses of fertility. In other words, one crop helps to prepare the soil for another or for the following one. Additional elements influencing yields are seed selection, preparation of seed bed, winterkilling, wind injury and the activities and control of injurious insects and plant diseases.

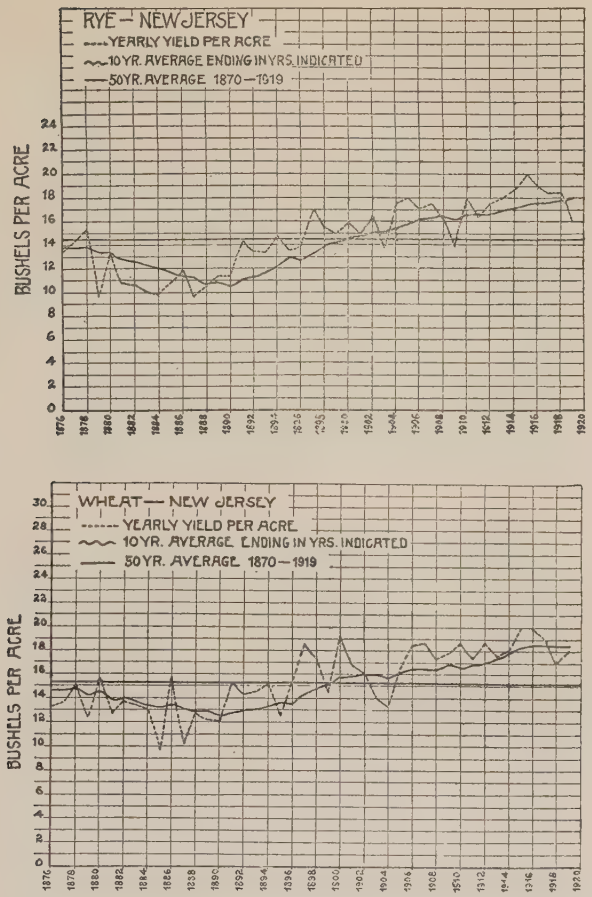
Having thus briefly and generally covered the more important factors bearing upon yields, let us turn our attention to the charts showing the curves of yearly average yields per acre, together with ten-year averages and the fifty-year average for the important field crops of New Jersey. The ten-year average curves are based on the yearly averages, this resulting in lines which are much easier to follow. It is with such curves that we will deal principally. As shown in the chart, the average yield of corn began to decline below the fifty-year average about 1883 and continued until 1890 when the lowest point was reached. From 1891 it rose slowly but not until 1909 or 18 years later did it reach the fifty-year average again. From 1891 however the ten-year average slowly increased. Buckwheat dropped below the fifty-year average line about 1881 and further declined until 1890 when it reached its lowest point. From then on it increased sharply until 1899, when the fifty-year average was reached and continued less sharply from that date. Rye began to decline in average yields in 1881 and reached a low level in 1890, after which it gradually increased. Wheat followed a course similar to that of rye. The ten-year average curve for oats shows little variation for the entire period. The hay curve shows a slight decrease about 1880 and continues down until 1889. From 1890 on it rises slowly. The potato curve shows little variation until 1902 after which date it climbs steadily. The sweet potato curve indicates a steady increase in average yields from 1878 on with the greatest rate of increase taking place after 1899.

Comparison of Ten-Year Average Curves

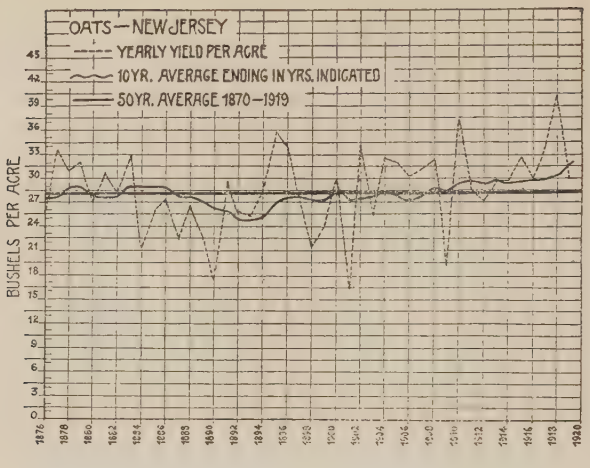
Crop	Decline begins	Lowest point reached	Increase begins
Corn	1883	1890	1891
Buckwheat	1881	1890	1891
Rye	1881	1890	1891
Wheat	1881	1890	1891
Hay	1880	1889	1890
Potatoes (white)			1902
Sweet potatoes			1899

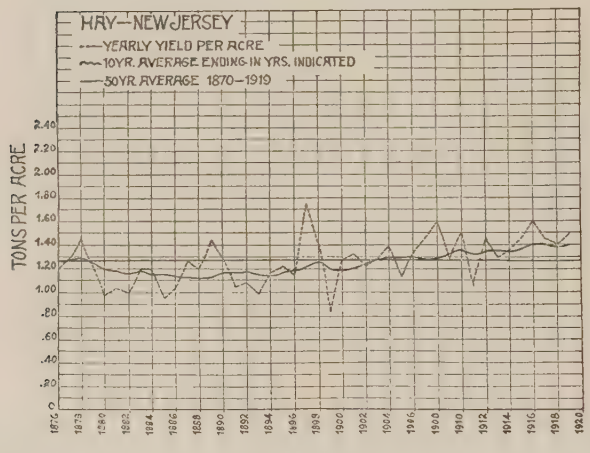
From 1880 to 1883 all of the above crops except white and sweet potatoes began to yield less, the lowest points being reached in the years 1889 and 1890. From 1891 on, the average yields of most gradually increased, potatoes, sweet potatoes and buckwheat at a faster rate than corn and hay.

In an attempt to explain the causes underlying the dips and rises in the ten-year average curves, the climatic factor can be ignored. It is difficult to find any single definite reason which will account for the declines in the cases of corn, buckwheat, rye, wheat and hay from 1880 to 1890. It was suggested that a loss of the natural fertility might


RYE — NEW JERSEY
YEARLY YIELD PER ACRE
10 YR. AVERAGE ENDING IN YRS. INDICATED
50 YR. AVERAGE 1870—1919
BUSHELS PER ACRE
WHEAT — NEW JERSEY
YEARLY YIELD PER ACRE
10 YR. AVERAGE ENDING IN YRS. INDICATED
50 YR. AVERAGE 1870—1919
BUSHELS PER ACRE

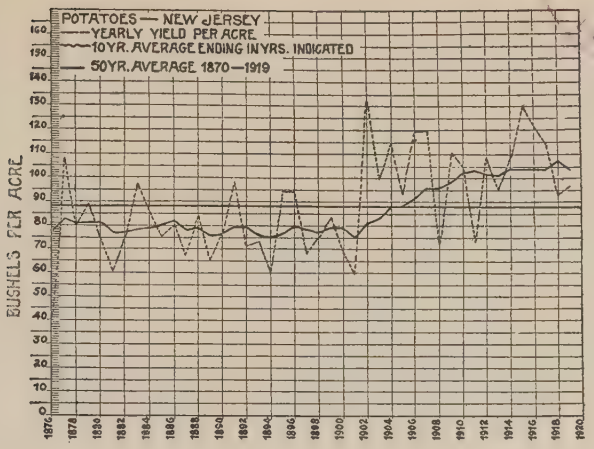
have taken place at that time but this is not possible because the cultivation of the soil in New Jersey was neither intensive nor long continued enough by 1890 to produce such a state of affairs. It was also suggested that this decline was probably due to the fact that the farmers at that time were not getting enough money for their products to warrant the purchase of fertilizers. A study of the prices received by New Jersey farmers for their products from 1866 to 1920 as shown by the chart in which corn, wheat and potato prices are plotted as fair examples, indicates that while prices from 1880 to 1890 were low compared with the prices for previous years, they were on the whole slightly higher than the prices received from 1900 to 1910 during which time more commercial fertilizers were being used and yields were increasing. However between the years 1880 and 1890 the prices of farm products were undoubtedly dropping faster than the prices of manufactured articles and such a condition would lead to retrenchment on the farms. Dr. Jacob G. Lipman, director of the New

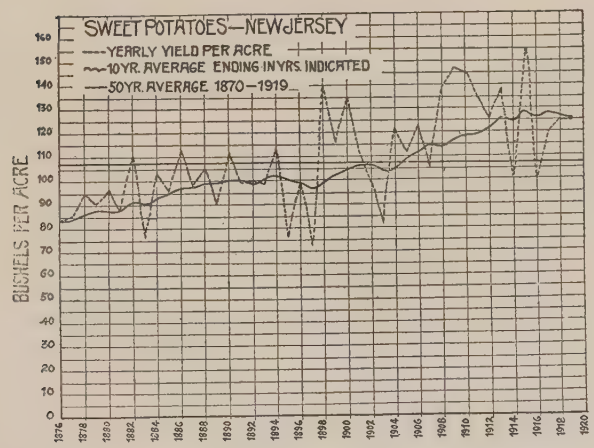




Jersey Agricultural Experiment Stations, informs me that the early '80's marked the end of the extensive use of greensand marl in New Jersey and that commercial fertilizers were just beginning to come in. With the discontinuance of the extensive use of marl after 1875 and the lack of familiarity on the part of the farmers with commercial fertilizers, there was naturally a period of depression in the fertility conditions.

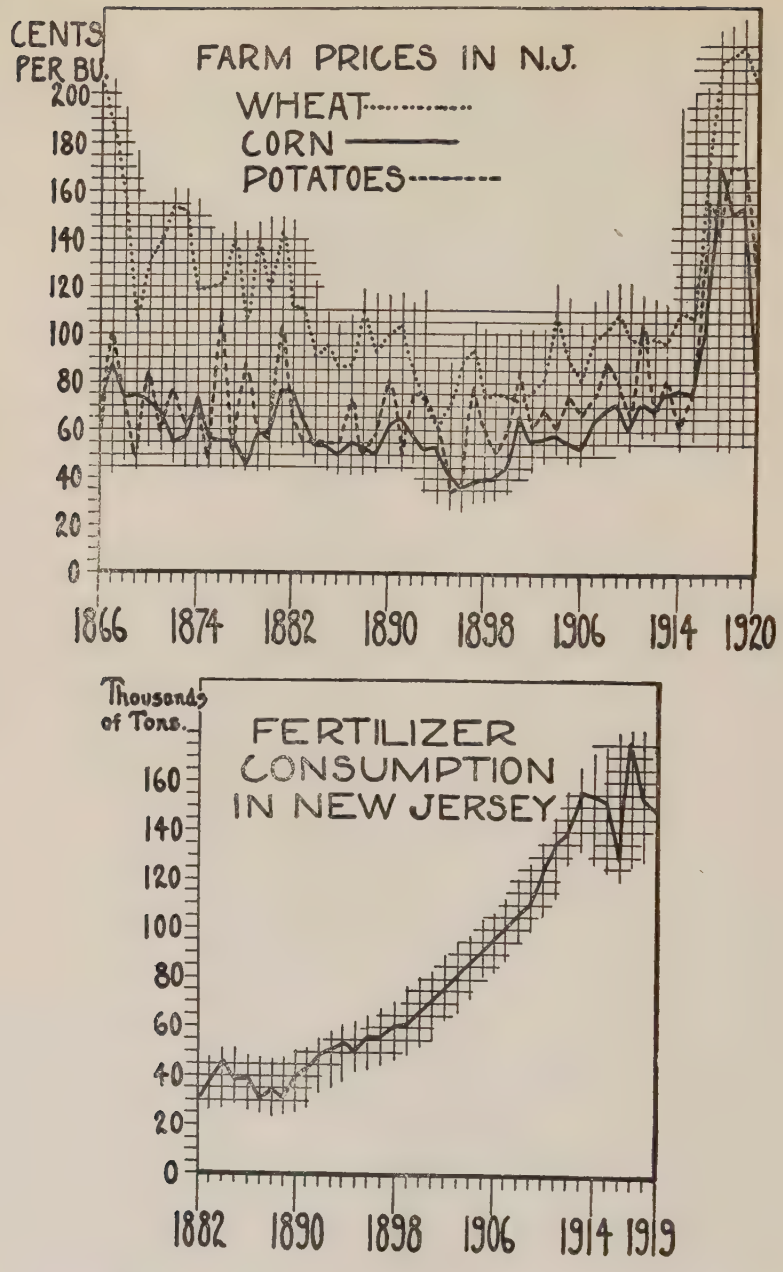
There is the additional fact to consider that in the early years statistics were not gathered as accurately as they were later, and in view of a lack of figures on which to compute ten-year averages before 1876 the declines between 1880 and 1890 may quite possibly be parts of a more or less natural cycle such as one might find when considering such variable items as yields and the factors influencing them over a long period of time. Moreover, for the most part, the declines are




SWEET POTATOES—NEW JERSEY
YEARLY YIELD PER ACRE
10 YR. AVERAGE ENDING IN YRS. INDICATED
50 YR. AVERAGE 1870—1919
BUSHELS PER ACRE

not startling as will be seen by examining the scale of the charts and may represent simply a low level in production.

The rises of the ten-year average curves are of more interest. These show no tendency to follow definite cycles arrangeable into up and down periods, at least not for the thirty-year period from 1891 to the present time. Practically all of them except the one for oats show a more or less gradual increase from 1891 on. In explaining the reason for this, some light may be thrown on the subject by noting the graph showing the rapid growth in the use of commercial fertilizers in New Jersey. The New Jersey Experiment Station was established in 1880 and its work in developing the knowledge of the use of commercial fertilizers is one of the outstanding services that it has rendered. From 1882 to 1890 the nine-year average consumption was about 36,000 tons. From 1890 on, the tonnage gradually increased until at



the present time about 150,000 tons are used each year. At present there is a more or less marked tendency toward the use of more concentrated fertilizers, which means that a smaller tonnage is furnishing the same amount of plant food formerly furnished by a larger tonnage. The curve of fertilizer consumption from 1890 on fits in nicely with the ten-year average crop yield from that date and it is

reasonable to assume that such fertilizers are in part responsible for the increase in average yields. This is especially true for potatoes on which comparatively large applications are made and to a less extent for sweet potatoes. Both are cash crops.

About 75 per cent. of the fertilizer tonnage is used in the southern two-thirds of the state and some of this is used for crops not considered in this paper. It is in this section that the bulk of the white potato and all of the sweet potato crops are grown. North of where most of the commercial fertilizer is used, are found the bulk of the wheat crop, about one-half of the rye and practically all of the oat and buckwheat crops. Corn and hay are generally distributed over the entire agricultural section of the state. The slow rate of increase in hay yields is undoubtedly due to the fact that in the usual rotations practiced in New Jersey, hay follows such crops as corn, potatoes and wheat and does not receive fertilizer applications to the same extent as other crops. Oats not being a cash crop would naturally receive less attention than the others and this accounts for the little variation in the ten-year average curve. In the potato, sweet potato and tomato sections of the state, other crops like corn and grass are the beneficiaries from the use of large amounts of fertilizers. Buckwheat, which is a minor crop, has received little or no attention in the way of improvement. It is a crop which yields well on poor land. According to the chart this crop shows a somewhat higher rate of yield increase than the others. This is due to the fact that it has ridden in on the crest of the improvement wave and its success insofar as increased yields are concerned is due to the improvement which took place generally.

In addition to the increased and intelligent use of commercial fertilizers, which appears to be the most important factor, other factors which have played their parts in helping to increase yields and which are of varying degrees of importance, are improved methods of soil management, seed selection particularly in the case of corn and potatoes during the past few years and increased efficiency in controlling injurious insects and plant diseases. It may also be noted that the introduction and extension of the acreage of alfalfa and the more intelligent growing of other legumes have played a part in the improvement of the productive power of the land. Some of the more common legumes, like soybeans, cowpeas, crimson clover, alfalfa and vetch, have been introduced into the state since 1880, although small acreages of some were known before that date.

These increases in yields can be taken as part of the evidence that farming is becoming more efficient and credit is due to all agricultural agencies in the state which have contributed toward this result by advocating and striving to advance new or better methods.

THE PLAY OF A NATION

By Professor G. T. W. PATRICK
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IF we use the term play quite broadly to include all forms of sport, recreation and relaxation, then it is evident that in work, sleep and play most of our time is spent. Excepting the very young and the very old, we sleep on the average about eight hours of the twenty-four. Most of us work at something or other eight or ten hours, more or less. This leaves six or eight hours for recreation and relaxation.

Of course there are other ways of passing the time not strictly included either in work, sleep or play, such, for instance, as eating and love-making, the latter, although a serious and instinctive form of behavior, often infringing upon or wholly absorbing the hours claimed for recreation.

Even at the worst, however, a good many hours of every day, say two, four, six, eight, ten, are spent in some form of play. Since we in America number more than a hundred million people, it follows that a good many hundred million hours are daily spent in something which goes by the name of play, be it recreation, relaxation, sports or pastimes.

Now there are certain psychological laws by which the value of play may be tested, enabling us to say in advance to what extent it is real play having restorative and recreational value. In the light of these laws, it will be interesting to study the actual plays of our American people, for our national health and our social welfare, as well as our personal health and happiness, depend a good deal on the character of our play.

When we think of our national sports, baseball comes to our minds —and football and basketball and golf and tennis. When we think of our recreations, perhaps music suggests itself or the theatre or special individual pursuits and interests. When we use the word play, probably we visualize children at some indefinite game—say hide-and-seek.

But a moment's reflection will show us that in the lives of our hundred million people the time actually spent in any of the above pursuits is very little. Evidently, if this study is to be of value as a social survey, we shall have to be more concrete, or even get into a statistical mood.

How then do we as a people actually pass our hours of recreation or relaxation? Well, some of us read, say newspapers or magazines or books of fiction, some of us smoke or even drink, some make social calls or just lounge and chatter, some simply sit, some talk or fuss or gossip, some play pool or billiards. A very large number go to the movies. Some play bridge. Some play poker or shoot craps. Some bet on baseball, football, or horseracing. Many ride in motor cars. Occasionally one or two ride horseback. A few walk. A very few swim or exhibit themselves in scanty costumes with the ostensible purpose of swimming. Once in a while one may go to the gymnasium. Some play golf or tennis. A large number dance. A few go fishing or hunting or camping. A certain number actually participate in baseball, football or basketball.

This is not intended as a complete list of our recreational activities but may afford a basis for the present study.

We in America live rather a tense life, under high pressure. Our diversified interests, our many social duties, our multitudinous responsibilities, our insistent worries, even our stimulating climate combine to make our modern life very strenuous, taxing our minds and bodies to the limit. Many succumb to the rapid pace and neuroses of various forms increase. In a way we are all at the front and in the trenches and shell shock is getting to be pretty common. Hence, the need of relaxation, recreation and play. Psychologists, social workers, religious workers and employers of labor have all awakened in recent years to the importance of play.

But play in order to be recreative must conform to certain requirements. All plays are pastimes but not all pastimes are play. Some of them seem merely to satisfy a longing for excitement. Why is it, since our whole modern life is so exciting as compared with former ways of living, that in our leisure hours we seek exciting pastimes? Why the craving for gambling, for alcohol, for tea and coffee and all sorts of stimulants? Why do we not seek rest and complete relaxation—a letting down and slowing up of our rapid pace? Why the demand for stimulating drinks, stimulating moving pictures, stimulating risks in gambling, stimulating speed in driving? Why the dancing craze and the amusement craze which at first sight would seem to increase our fatigue rather than allay it?

Fortunately the psychologists have worked out the problem for us and we now understand fairly well the psychology of play. We have learned that it is not excitement that we seek in play but release from those forms of mental activity which are fatigued in our daily life of grind. Play, if it is to be real play, that is if it is to have recreational value, must be of a sort to relieve those parts or tracts of the brain which are overtaxed in our daily life of work and worry. It must be

essentially different from our work, opposite in every respect. The work-a-day world of the present involves certain mental processes which are comparatively late in development in the long history of human evolution, such, for instance, as concentration, analysis, abstract thought, sustained attention, sustained effort, and controlled association, while the exigencies of our social life demand the constant checking or inhibition of a vast number of natural impulses and appetites.

The result is that that manner of cerebral functioning with which these higher intellectual and volitional processes are associated is brought under a severe stress and strain, leading to rapid neural fatigue and an urgent demand for rest and relaxation. It is not more sleep that is needed, nor rest of the whole body and brain, but relief from that special kind of activity so stressed in our modern competitive life. It is probably just for this reason that we crave alcohol and tobacco because they are not stimulants but narcotics, putting a temporary quietus upon just these overworked forms of cerebral activity.

Figuratively speaking, we may say that what is needed is that kind of activity which will relieve the higher brain centers, while allowing the older and lower ones to function. This is not strictly accurate from our present day conception of the brain. What really happens when we think hard, pay attention closely, decide quickly, or hold our mind steadily to a given task, is better expressed as a kind of total integration of cerebral processes, these processes taking the form probably in all cases of reflex arcs or reaction arcs, as we now call them. This total integration of brain processes is impossible for children and extremely fatiguing for adults. Children therefore must play all the time and grown-ups much of the time, if break-down is to be avoided; and by play we mean here some form of activity which does not involve this total integration of the brain areas.

Play then to be wholesome and truly recreative must involve only those areas of the brain and those parts of the nervous system which in the evolution of man are old and pervious and easy. They are, so to speak, the brain channels which are deep-worn and natural. The muscular responses in play must be those which past ages and long usage have made easy and familiar. We see, therefore, why the plays of children repeat the life history of the race. The cave, the tree-house, the swimming pool, the camp-fire, the bow and arrow, the canoe, the jack-knife, the ball bat, the mimic fight, kites, tops, marbles, hunting, fishing, gathering nuts, the cat, the dog, the teddy bear, the horse-race, the game of hide and seek, the charms and talismans and superstitions—all these are, as it were, reminiscences of the past life of the human species. They involve brain patterns that are old and familiar, the only ones in fact that are developed as yet in childhood

and the ones that in adult life give rest and release from the fatiguing activity of the higher brain centres continually stressed in our daily life of grind.

As a rough rule we may say that the more primitive a sport is the higher its recreational value. Good sports, therefore, are those which involve these older brain patterns and this criterion we can use in judging the recreational value of our sports and pastimes today.

The elements of rivalry, competition, and contest, as ancient forms of self-expression, act as purifying motives in all good sports. When these are absent, as in the moving pictures, the dance, and the automobile, the recreational value of the play falls off a little. In human society, especially in our modern crowded social groups, we are obliged to live together in peace and harmony and have to inhibit and suppress a great many of our natural and ancient feelings of rivalry and hatred. This constant suppression of our egoistic impulses results in many serious mental complexes. Games of rivalry thus provide a compensatory element, purifying the mind. This explains why there is so great a demand for games in which this element of rivalry takes a very direct and primitive form—the form of a regular face to face battle—as in prize fighting and football, and we understand why immense crowds flock to these sports.

I know a husband and wife who live together in great peace and happiness. They play once a day a game of backgammon in which all their pent-up and unconscious animosities are given full expression. During the time of this game they exhibit the most ruthless antagonism, showing no mercy to their opponent but bent on his complete destruction and annihilation. It is a fight to the finish.

But there are other rules by which to measure the value of our play. Since our modern work-a-day world, at least in our American climate, is to a large extent sedentary, confined and indoors, our sports to be of the greatest value must be out-of-door sports.

Finally, our sport must provide for self-expression. In self-expression there is a mystical recreational power. Nothing rests one so much as victory, pursuit and capture. All good games introduce the element of rivalry.

Now, equipped with these tests and measures of good play, sports, and pastimes, we are prepared to examine the actual recreations of our American people to see whether they stand the tests. And we have already discovered what these sports and pastimes are and have only to enumerate them again. If we attempt to name them roughly in the order of their prevalence, the order would seem to be something like this: Reading, movies, dancing, motoring, walking, card games, pool, baseball, golf, tennis, football, basketball, swimming, fishing, hunting, camping, gymnastics, and horseback riding. Such a classification must

be very general and even the most popular of these pursuits might be surpassed in popularity by other less definite forms of recreation or relaxation such as sitting, talking, gossiping, fussing, lounging, smoking, drinking, gambling, shopping, etc.

Applying our tests to these forms of play, it becomes clear at once that golf, tennis, baseball, football and basketball stand out pre-eminently as real recreative sports. From the psychologist's point of view, golf may be cited as the perfect ideal sport. It has all the needed recreational elements. It has a restorative power excelling all therapeutic arts. It represents a reversion to the natural outdoor life. We range over hills in the open, using the muscles of the legs, arms, and trunk. We carry a club and strike viciously at a ball. We search for the ball in the grass as our ancestors searched for their arrows. There is a goal and the spirit of rivalry and a chance for self-expression. The nerve currents course through ancient channels. We return to our work refreshed and rejuvenated. Golf, to be sure, requires fine adjustments of eye and hand at the moment of striking but there is no continuous strain upon them and skill of this kind is a proper element in play. It is unfortunate that the opportunities for golf are now limited to the few. Nothing better could happen to our nation than a wide extension to our people of the opportunities to play golf.

As regards tennis much the same may be said. Though lacking some of the distinctive psychological elements of perfect sport possessed by golf, it is still a very excellent and healthful form of recreation. Opportunities for it should be widely extended.

Baseball and football have certain peculiar qualities which rank them as high or possibly even higher than golf. Being more strenuous, they are better suited to the young males, while golf and tennis may be played by all. We see at once that football meets all the conditions which we have outlined as marks of good sport. There is running, kicking, dodging, tackling, pursuit and capture. There are also the opposing groups, as in battle, and the rough rude shock of personal collision. All these ancient responses offer complete relaxation and release from the proper and pent up inhibitory life of our modern world. They arouse latent, deep-seated instincts and impulses, allow us to revel for an hour in these ancient memories and restore us to our work refreshed and purified. It is the grip upon us of that which is racially old which explains the immense throngs which gather at the football games. Seventy or even a hundred thousand spectators have been reported at some of the great games.

The racial elements in baseball are not quite so old but are sufficient to permit the *catharsis* element in rare degree. Striking and throwing are dear to every boy, and these ancient responses, the ancestral conditions of race survival, are dominant in baseball, while the running and

catching, and the opposition of the teams, and the reward of skill and of strength and quick decision add to the real recreational value of the game. The recent extension of non-professional baseball and football among school boys is a contribution to social welfare. Here again, however, the application of the statistical method awakens our concern. For if baseball is fitted to all young men from the ages of fourteen to thirty, actual regular participation in it will be found to be limited to relatively few. It should be extended to a larger number.

But professional baseball as a national sport presents a different problem. Here the "players" are not playing but working. The game is a profession, a strife for glory and for money. The recreational features are now transferred to the spectators. To what extent is baseball of recreational value to the fans? They usually ride out to the ball park in auto or street car, sit on the bleachers during the game and return as they go. Nevertheless the game has considerable recreational value for the spectator. The galling social checks and inhibitions of the daily grind are thrown off for a time. Free expression is given to one's feelings and enthusiasms. There is a mental participation in the game and no doubt usually a considerable degree of rest and relaxation is gained. But it does not permit of self-expression and is far from an ideal form of play and at the best the number enjoying it is relatively small. Basketball, though lacking in some of the distinctive recreational elements of baseball and football, is nevertheless of the greatest value as a sport and stands high in our list.

Hunting and fishing, swimming and camping constitute a group of sports which rank high in the list of valuable recreations. They represent a return to the conditions of primitive life and involve only racially old and familiar brain patterns. They are out-of-door sports, using the fundamental muscles of the arms and legs and completely releasing the strain upon the eye and hand and nervous system. Hunting with the camera, recommended by the humane societies, is well enough, but the camera it not a substitute for the gun in recreational value. When we consider the horrors of the late war and remember that if the nervous tension of a people gets too high it may overflow in an actual orgy of human bloodshed, the "cruelty" of hunting and fishing seems less serious, especially if they act as a release of the nervous tension increased by our high pressure modern life.

Swimming as a form of play stands very high. It is unfortunate that so fine a sport should be degraded by the entrance of other elements, such as sex and dress, which detract from its pure recreational value. On the whole the reviving interest in swimming, bathing and camping, in the Boy Scout movement, in the Campfire Girls' movement, and in the whole outing cult in general, is a most encouraging sign. These are healthy forms of play.

But here again, if we count noses, how many of our hundred million people are able to avail themselves of these sports? The relative number of those who actually do engage in any of them sufficiently often to serve the purpose of recreation adequately is rather small. Opportunity for them is lacking among the greater number of our people both young and old. One-half of our whole social group, namely girls and women, are at once debarred from participation in most of the sports thus far discussed, excepting only tennis and swimming and perhaps golf.

We have therefore to consider now the value of the forms of recreation in which there is actual participation by large numbers of our people of both sexes, young and old. Motoring first demands our attention. As there are more than eight million automobiles in the United States, as most of these are kept pretty busy through many if not all months of the year, as each one may carry several people of both sexes, old and young, and as a considerable proportion of this riding is for purposes of recreation, we see at once that we have here a form of play of very wide extension. What is its value as determined by our psychological tests? Well, it is out-of-doors at any rate. Fresh air is furnished in abundance, and for our indoor workers that is certainly something. Man is by nature a roamer. He resents confinement. He must have a change of scene. He loves adventure. For old men and house-pent women the motor car is a boon. For workers whose daily tasks keep them on their feet, the automobile is a rest and comfort. It has also another recreational feature, namely, speed. The craving for speed, which gives zest to coasting, skating, and flying, is probably a survival of the ancient joy of pursuit and escape.

Nevertheless, for the average man and woman, and especially for the child, the automobile is anything but a blessing as a form of play. For hundreds of thousands of years the human being has lived on his feet and made his living by means of his legs. Now he has become, to a considerable extent, a sitting, lounging, reading, studying, and thinking being, and a whole group of new diseases has followed this sedentary life. It is by no means certain that a sitting race can survive. The motor car deprives many people of the little walking which they would otherwise do. Each new car advertises softer cushions, an easier upholstered back to support the shoulders or even the head, and more delicate springs to ward off every jar. The ease is seductive and we ride even to our offices or places of business.

With horseback riding the case is wholly different. Here, to be sure, the legs are not used, but a whole series of valuable psychological factors are present which make this one of the best of all sports. The horseback rider does not need the offices of the osteopath or chiropractor; his spinal column gets the necessary limbering up; and the

mere association with horses adds a subtle historical element of the greatest value. The automobile is suitable for convalescents.

Walking is not usually classified as play. It is nevertheless of exceedingly great value as a means of recreation for sitting people. It lacks many of the prime features of play but it is at any rate always available and may easily be a life saver.

So we come in the end to the dance and the moving pictures, for we may leave out of consideration a long list of recreations whose value the reader may easily appraise by using the tests which have been enumerated, such for instance as pool, billiards, card games, reading, gossiping, gambling, etc.

If, as we are told, twenty million people, men, women and children visit the movies every day, we have at least one form of recreation which even by the statistical method actually reaches the whole population without distinction of age, sex, or social status. The moving picture theater is everywhere, in the large city accessible almost without the use of a street car, in the country town more prominent than the church and school house. The price of admission is so moderate that the poorest may attend, while evening, afternoon, and Sunday exhibitions make the time convenient for all.

The dance is not quite so universal as the movies but is widely enjoyed by both sexes in city, town, and country.

What is the recreational value of these two universal forms of play? If we refer again to our table of tests, it would seem that the dance meets all the conditions except the out-of-doors requirement. It is an ultra-primitive form of human activity, as old as mankind itself. It relieves completely the strain upon the eye and finger muscles, involving only the ear and the larger muscles of the trunk and legs, the rhythmical movements being ancient, easy, and natural. The higher brain centers are completely rested, for they have nothing to do. The brain patterns of the dance are the simplest conceivable, being very old and familiar. There is a thrill of cherished memories associated with the dance in the life history of the race. This explains in part its fascination. When social restrictions are lifted, the craze for dancing bursts upon a sitting and sedentary race almost with the furor of an epidemic. A tired and nervous people finds here its release, a relaxation complete and satisfying. There is opportunity also for self-expression.

The more primitive the manner of dancing becomes the greater its charm. The recent revival of barbaric syncopated forms of music to accompany the dance and the still further reversion to steps and attitudes of the most primitive type heighten the joy and accentuate the recreational effects.

But it is right here that we encounter certain serious difficulties with

the dance as a means of recreation. We live in highly complex social groups, in which other factors than merely physiological and psychological ones count. The social and moral aspects of every form of recreation have to be considered. The modern dance owes its attractiveness, not wholly but partly, to the sex motive. To that extent it passes out of the sphere of play activity into the wholly different sphere of love-making. As such it does not come within the purpose of this paper. This mixture of motives, however, very greatly lessens the value of the dance as a form of recreation, excepting of course the graceful and healthful forms of folk dancing, the revival of which is a sign of hope.

Still other factors lessen the value of the dance as recreation. Not only is it indoors; it is largely a night pastime and has incidental associations of late hours, extravagance in dress, and moral surroundings not always good. On the whole, it may probably be said that while from the standpoint of the individual the dance in itself has unlimited possibilities as recreation, from the standpoint of social health and welfare the results are bad.

If we consider the esthetic dances and the esthetic factor in all dancing, a point in favor of the dance may be urged. No recreational force could be imagined better for a spent and nervous people than the enjoyment of beauty in all its forms. Could the attention of the American nation be diverted for certain hours of the day or week from its feverish pursuit of wealth and power to the quiet enjoyment of beautiful things, its salvation would be insured. Of all the forms of esthetic enjoyment, that of music is the most restful, harmonizing, and tranquilizing. And this is not altogether due to the intrinsic excellence of music over the arts of painting, sculpture, architecture and poetry, although even that claim might be urged. The restful and recreational value of music for our people is due in a peculiar way to the fact of our prevailing eye-mindedness and finger-mindedness. In music we find our release. It is thus a hopeful sign for the permanence of our civilization that in our public schools a constantly increasing time is given to music and the other fine arts.

The compensatory character in play which we have emphasized is incidentally well illustrated by the wave of jazz that has swept the world and now spent itself. Ethically and esthetically no music could be worse than this. But as a temporary restorative of nerves shattered by a terrible world war, no music could be better. For the moment the world needed a complete release, a primeval pacifier. It seized with joy upon the music and the dance of primeval man and perhaps for the same reason has reverted in other ways to primeval practices and morals. Having thus been flushed and purged, the toiling upward way may again be undertaken.

As regards the movies, one point in their favor has been noted. They are accessible and available. They satisfy vicariously the love of adventure, the roaming instinct, the delight in the new and the strange and the wonderful. They are absorbing, diverting the weary soul from its troubles. They relieve the strain upon the will by the plot-interest, which carries the observer along without effort. They bring a glimpse of fairy land into some lives that are drab and prosy. Those who cannot even dance may here participate in the sight of dancing. To those who have no beauty in their daily surroundings, beauty is brought in many forms upon the screen.

But when this is said, all is said, for if we refer again to our table of tests of recreational factors, we find nearly all the elements of good play wanting in the movies. Good play is out of doors and involves the larger fundamental muscles of the trunk and legs, and for children this is primary and indispensable. They must be active in play and all sedentary people must be active in play. It is bad enough that children should be confined in a school-room five precious hours of the day. It is worse if they are penned in between a desk and a seat. For such children to spend still other hours of the day or evening or any hours of their holidays in confinement is serious, and especially in these days of universal reading, when old and young alike spend so many hours sitting, reading fascinating books of fiction, and interesting magazines and papers.

In the moving picture theater the bodily confinement is complete and uncompromising. In the school-room the child can at least wriggle. In the movies the attention is so wrapt as to result in a statue-like rigidity of the whole body for hours. For adults this is unfortunate; for children it is fatal. Many moving picture theaters are stuffy. Most of them are crowded. The physical conditions are thus the worst possible from the standpoint of recreational needs.

As regards the use of the sense-organs, the eye, overworked among our modern reading people, gains no rest from moving pictures but is taxed to the very utmost and kept under strain for hours. To what extent the eyes will suffer from the moving pictures I am not here discussing. I am only pointing out the failure of the movies to conform in this respect to recreational requirements. The relations of the eye and ear to our modern life are such that good music is of far greater value as recreation and relaxation than any appeal to the eye. If our play is to take the form of any entertainment on the stage, good music in any form, whether in concert, recital, folk songs, or opera, would seem to be deserving a very high place.

Incidentally it should be mentioned here that in the history of the race the most intimate and human relations are associated with the voice as used in speech. The Greek tragic drama, which drew whole

populations of a city to the outdoor stage, depended for its powerful appeal largely upon the human voice. The spectacular character of the modern theater seems like a distinct loss. But when this is carried, as in the moving pictures, to the point where human life and society are wholly divorced from the expressive and meaningful tones of the voice, we seem to be living in a dessicated and dehumanized world, from which all intrinsic worth has departed. The visual world depicted on the screen has movement, plot-interest, strangeness, novelty, excitement, intensity, but lacks the elements which are soothing, tranquilizing and harmonizing. It is neither relaxation nor recreation.

Another aspect of the moving pictures in their relation to the human mind, which must be taken into account, is their effect upon the emotions. Aristotle's catharsis theory of the drama has been long discussed. The mind is supposed to be purified by such mild excitement of the emotions of pity and fear as is offered by the tragic scene upon the stage. Our pent up emotions are supposed to demand expression and the drama serves as a kind of safety-valve, allowing the emotions a legitimate and harmless outlet.

There is scant psychological evidence to support this theory. The emotional flooding of the mind which the spectator experiences probably has no recreational value in itself. In the legitimate drama this tumult of the emotions, tempered by the human voice and by all the settings of real art, may be for the adult a harmless accompaniment of esthetic enjoyment. In the moving pictures such frequent and excessive overflow of the emotional life can hardly fail to disturb the delicate balance between real life and its natural emotional response. Certain films widely exhibited to large audiences draw too heavily upon the emotions. Old time revivalists have been censured for working upon the feelings of their hearers by appeals to the very intimate and personal experiences connected with birth, death, and marriage. These tales were innocent compared with the harrowing scenes sometimes presented on the screen. Tears flow and the breast heaves but the natural expression of emotional states through action is prohibited. In real life such emotional situations lead to action. In the movies nothing happens. The natural response is lacking.

We must conclude therefore that from the standpoint of the psychology of play, the movies offer little of recreational value, while for children they may be the source of the most pernicious mischief. The physical decadence which is anyway threatening our people because of our modern life of comfort, ease, and inactivity, with its excessive demands upon the brain and its neglect of physical development, is likely to receive a considerable impetus from the moving pictures.

As I am speaking here of recreational values only, I need not dwell on the moral influence of the movies. Neither can one pass the sub-

ject in complete silence. From this point of view one needs stronger phrases than "a national calamity" and "the world's worst failure," which have recently been applied to these pictures.

Hitherto humanity by tacit and universal consent has been willing for the sake of the innocence of its children and the purity of its women to draw a veil before the worst evils of the world, and by a delicate instinct to touch lightly and reverently upon its most sacred institutions. It has always been assumed that there are some things too sacred, some too intimate to be exposed to public view. But in the moving pictures all is cheapened. The veil is ruthlessly torn from everything, and for commercial motives only.

The pernicious effects of flaming abroad to every town and countryside moving pictures of the most decadent phases of city life must be apparent to everybody, but to introduce our young children to all this seems like social suicide. The plot-interest of a cheap play we enjoy for an hour but the plot-interest in life itself is discounted in advance and deadened. The moving picture concerns say that the public demands sensational and erotic pictures. That an enlightened social community should allow great commercial interests to exploit its children for motives such as these is beyond belief. Certainly we are a complacent people.

When society comes to its senses and sweeps the bad pictures from the stage, then the question of the recreational and educational value of the movies will be more carefully raised. The recreational value, as we have seen, is slight, while the educational value has been greatly overestimated. The child, as any educator knows now, learns by doing, not by seeing. The moving pictures may bring to the child a visual image of many things but what is more important is that he himself should learn to contribute to human utilities, that he should take his part in life, that he should learn to control himself, to express himself, to read and write and speak correctly, that he should know how to appreciate good language, good books, good music, and good art, that he should conduct himself as a responsible moral being in the family and in the social group. These things cannot be learned by seeing them on a screen. They must be learned by long and persistent training in the actual doing.

In conclusion, it would seem that in regard to the actual present day recreations of the great body of our American people, the three which rank highest in respect to the numbers participating in them, namely, the dance, the movies, and the automobile, do not rank high in real recreational value while one of them has a doubtful social value, and one a widespread pernicious influence.

Mr. Chesterton says that our modern people do not know how to amuse themselves because they are not free men. Our amusements are

mechanical, as our whole life is. We have to be amused by machinery, such as the cinema and the automobile. True recreation is that in which we ourselves participate. There must be action and self-expression.

It will not do to lay all the evils of the present time—and they are very threatening—upon our institutions nor upon the war. To a considerable extent they have their source in the unstable brain of the individual. Our material and social environment is changing very rapidly while the human brain and body are changing little or not at all. Hence, we are not adjusted to our environment and social irritability results, venting itself usually in an attack upon our political institutions.

Nothing would do more towards the solution of our social problems than providing healthful and harmonizing recreations for the nation. The way to do this may be beset with difficulties but the true approach seems to be through the public schools. The cultivation of good taste in selecting our amusements would do something, but practical results will be more likely to follow the enlarged opportunities for good sports and healthful plays and a revision of our school program in the direction of the English system, in which sports and play are an integral part of the public school curriculum.

EVARISTE GALOIS

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NO episode in the history of thought is more moving than the life of Evariste Galois—the young Frenchman who passed like a meteor about 1828, devoted a few feverish years to the most intense meditation, and died in 1832 from a wound received in a duel, at the age of twenty. He was still a mere boy, yet within these short years he had accomplished enough to prove indubitably that he was one of the greatest mathematicians of all times. When one sees how terribly fast this ardent soul, this wretched and tormented heart were consumed one can but think of the beautiful meteoric showers of a summer night. But this comparison is misleading, for the soul of Galois will burn on throughout the ages and be a perpetual flame of inspiration. His fame is incorruptible; indeed the apotheosis will become more and more splendid with the gradual increase of human knowledge.

No existence could be more tragic than his and the only one at all comparable to it is, strangely enough, that of another mathematician, fully his equal, the Norwegian Niels Henrik Abel, who died of consumption at twenty-six in 1829; that is just when Galois was ready to take the torch from his hand and to run with it a little further. Abel had the inestimable privilege of living six years longer, and think of these years—not ordinary years of a humdrum existence, but six full years at the time that genius was ripe—six years of divine inspiration. What would not Galois have given us, if he had been granted six more such years at the climax of his life? But it is futile to ask such questions. Prophecies too are futile, yet a certain amount of anticipation of the future may be allowed, if one does not contravene the experience of the past. For example, it is safe to predict that Galois' fame can but wax, because of the fundamental nature of his work. While the inventors of important applications, whose practical value is obvious, receive quick recognition and often very substantial rewards, the discoverers of fundamental principles are not generally awarded much recompense. They often die misunderstood and unrewarded. But while the fame of the former is bound to wane as new processes supersede their own, the fame of the latter can but increase. Indeed the importance of each principle grows with the number and the value of its applications; for each new application is a new tribute to its worth.

To put it more concretely, when we are very thirsty a juicy orange is more precious to us than an orange tree. Yet when the emergency has passed, we learn to value the tree more than any one of its fruits; for each orange is an end in itself, while the tree represents the innumerable oranges of the future. The fame of Galois has a similar foundation; it is based upon the unlimited future. He well knew the pregnancy of his thoughts, yet they were even more far-reaching than he could possibly dream of. His complete works fill only sixty-one small pages; but a French geometer, publishing a large volume some forty years after Galois' death, declared that it was simply a commentary on the latter's discoveries. Since then, many more consequences have been deduced from it, and Galois' fundamental ideas have influenced the whole of mathematical philosophy. It is likely that when mathematicians of the future contemplate his personality at the distance of a few centuries, it will appear to them to be surrounded by the same halo of wonder as those of Euclid, Archimedes, Descartes and Newton.

Evariste Galois was born in Bourg-la-Reine, near Paris, on the 25th of October, 1811,[1] in the very house in which his grandfather had lived and had founded a boys' school. This being one of the very few boarding schools not in the hands of the priests, the Revolution had much increased its prosperity. In the course of time, grandfather Galois had given it up to his younger son and soon after, the school had received from the imperial government a sort of official recognition. When Evariste was born, his father was thirty-six years of age. He had remained a real man of the eighteenth century, amiable and witty, clever at rhyming verses and writing playlets and instinct with philosophy. He was the leader of liberalism in Bourg-la-Reine, and during the Hundred Days had been appointed its mayor. Strangely enough, after Waterloo he was still the mayor of the village. He took his oath to the King, and to be sure he kept it, yet he remained a liberal to the end of his days. One of his friends and neighbors, Thomas François Demante, a lawyer and judge, one time professor in the Faculty of Law of Paris, was also a typical gentleman of the "ancien régime," but of a different style. He had given a very solid classical education not only to his sons but also to his daughters. None of these had been more deeply imbued with the examples of antiquity than Adelaïde-Marie who was to be Evariste's mother. Roman stoicism had sunk deep into her heart and given to it a virile temper. She was a good Christian, though more concerned with the ethical than with the mystical side of religion. An ardent imagination had colored her every virtue with passion.

[1] The biographical facts are borrowed from P. Dupuy's exhaustive biography, published in the "Annales Scientifiques de l'Ecole Normale Supérieure," t. xiii, Paris, 1896.

Many more people have been able to appreciate her character than her son's, for it was to be her sad fortune to survive him forty years. She was said to be generous to a fault and original to the point of queerness. There is no doubt that Evariste owed considerably more to her than to his father. Besides, until the age of eleven the little boy had no teacher but his mother.

In 1823, Evariste was sent to college in Paris. This college—Louis le-Grand—was then a gloomy house, looking from the outside like a prison, but within aflame with life and passion. For heroic memories of the Revolution and the Empire had remained particularly vivid in this institution, which was indeed, under the clerical and reactionary regime of the Restoration, a hot-bed of liberalism. Love of learning and contempt of the Bourbons divided the hearts of the scholars. Since 1815 the discipline had been jeopardized over and over again by boyish rebellions, and Evariste was certainly a witness of, if not a partner in, those which took place soon after his arrival. The influence of such an impassioned atmosphere upon a lad freshly emancipated from his mother's care cannot be exaggerated. Nothing is more infectious than political passion, nothing more intoxicating than the love of freedom. It was certainly there and then that Evariste received his political initiation. It was the first crisis of his childhood.

At first he was a good student; it was only after a couple of years that his disgust at the regular studies became apparent. He was then in the second class (that is, the highest but one) and the "provisor" suggested to his father that he should spend a second year in it, arguing that the boy's weak health and immaturity made it imperative. The child was not strong but the provisor had failed to discover the true source of his lassitude. His seeming indifference was due less to immaturity than to his mathematical precocity. He had read his books of geometry as easily as a novel, and the knowledge had remained firmly anchored in his mind. No sooner had he begun to study algebra than he read Lagrange's original memoirs. This extraordinary facility had been at first a revelation to himself, but as he grew more conscious of it, it became more difficult for him to curb his own domineering thought and to sacrifice it to the routine of class work. The rigid program of the college was to him like a bed of Procrustes, causing him unbearable torture without adequate compensation. But how could the provisor and the teachers understand this? The double conflict within the child's mind and between the teachers and himself, as the knowledge of his power increased, was intensely dramatic. By 1827 it had reached a critical point. This might be called the second crisis of his childhood: his scientific initiation. His change of mood was observed by the family. Juvenile gaiety was suddenly replaced by concentration; his manners became stranger every day. A

mad desire to march forward along the solitary path which he saw so distinctly, possessed him. His whole being, his every faculty was mobilized in this immense endeavor.

I cannot give a more vivid idea of the growing strife between this inspired boy and his uninspired teachers than by quoting a few extracts from the school reports:

1826-1827

This pupil, though a little queer in his manners, is very gentle and seems filled with innocence and good qualities. . . . He never knows a lesson badly: either he has not learned it at all or he knows it well. . . .

A little later:

This pupil, except for the last fortnight during which he has worked a little, has done his class work only from fear of punishment. . . . His ambition, his originality—often affected—the queerness of his character keep him aloof from his companions.

1827-1828

Conduct rather good. A few thoughtless acts. Character of which I do not flatter myself I understand every trait; but I see a great deal of self-esteem dominating. I do not think he has any vicious inclination. His ability seems to me to be entirely beyond the average, with regard as much to literary studies as to mathematics. . . . He does not seem to lack religious feeling. His health is good but delicate.

Another professor says:

His facility, in which one is supposed to believe but of which I have not yet witnessed a single proof, will lead him nowhere: there is no trace in his tasks of anything but of queerness and negligence.

Another still:

Always busy with things which are not his business. Goes down every day.

Same year, but a little later:

Very bad conduct. Character rather secretive. Tries to be original. . . . Does absolutely nothing for the class. The furor of mathematics possesses him. . . . He is losing his time here and does nothing but torment his masters and get himself harassed with punishments. He does not lack religious feeling; his health seems weak.

Later still:

Bad conduct, character difficult to define. Aims at originality. His talents are very distinguished; he might have done very well in "Rhétorique" if he had been willing to work, but swayed by his passion for mathematics, he has entirely neglected everything else. Hence he has made no progress whatever. . . . Seems to affect to do something different from what he should do. It is possibly to this purpose that he chatters so much. He protests against silence.

In his last year at the college, 1828-1829, he had at last found a teacher of mathematics who divined his genius and tried to encourage and to help him. This Mr. Richard, to whom one cannot be too grate-

ful, wrote of him: "This student has a marked superiority over all his school-mates." "He works only at the highest parts of mathematics." You see the whole difference. Kind Mr. Richard did not complain that Evariste neglected his regular tasks, and, I imagine, often forgot to do the petty mathematical exercises, which are indispensable to drill the average boy; he does not think it fair to insist on what Evariste does not do, but states what he does do: he is only concerned with the highest parts of mathematics. Unfortunately, the other teachers were less indulgent. For physics and chemistry, the note often repeated was: "Very absent-minded, no work whatever."

To show the sort of preoccupations which engrossed his mind: at the age of sixteen he believed that he had found a method of solving general equations of the fifth degree. One knows that before succeeding in proving the impossibility of such resolution, Abel had made the same mistake. Besides, Galois was already trying to realize the great dream of his boyhood: to enter the Ecole Polytechnique. He was bold enough to prepare himself alone for the extrance examination as early as 1828—but failed. This failure was very bitter to him—the more so that he considered it as unfair. It is likely that it was not at all unfair, at least according to the accepted rules. Galois knew at one and the same time far more and far less than was necessary to enter Polytechnique; his extra knowledge could not compensate for his deficiencies, and examiners will never consider originality with favor. The next year he published his first paper, and sent his first communication to the Académie des Sciences. Unfortunately, the latter got lost through Cauchy's negligence. This embittered Galois even more. A second failure to enter Polytechnique seemed to be the climax of his misfortune, but a greater disaster was still in store for him. On July 2 of this same year, 1829, his father had been driven to commit suicide because of the vicious attacks directed against him, the liberal mayor, by his political enemies. He took his life in the small apartment which he had in Paris, in the vicinity of Louis-le-Grand. As soon as his father's body reached the territory of Bourg-la-Reine, the inhabitants carried it on their shoulders, and the funeral was the occasion of disturbances in the village. This terrible blow, following many smaller miseries, left a very deep mark on Evariste's soul. His hatred of injustice became the more violent, in that he already believed himself to be a victim of it; his father's death incensed him, and developed his tendency to see injustice and baseness everywhere.

His repeated failures to be admitted to Polytechnique were to Galois a cause of intense disappointment. To appreciate his despair, one must realize that the Ecole Polytechnique was then, not simply the highest mathematical school in France and the place where his genius would be most likely to find the sympathy it craved, it was also a daughter of the Revolution who had remained faithful to her origins in spite

of all efforts of the government to curb her spirit of independence. The young Polytechnicians were the natural leaders of every political rebellion; liberalism was for them a matter of traditional duty. This house was thus twice sacred to Galois, and his failure to be accepted was a double misfortune. In 1829 he entered the Ecole Normale, but he entered it as an exile from Polytechnique. It was all the more difficult for him to forget the object of his former ambition, because the Ecole Normale was then passing through the most languid period of its existence. It was not even an independent institution, but rather an extension of Louis-le-Grand. Every precaution had been taken to insure the loyalty of this school to the new regime. Yet there, too, the main student body inclined toward liberalism, though their convictions were very weak and passive as compared with the mood prevailing at Polytechnique; because of the discipline and the spying methods to which they were submitted, their aspirations had taken a more subdued and hypocritical form only relieved once in a while by spasmodic upheavals. Evariste suffered doubly, for his political desires were checked and his mathematical ability remained unrecognized. Indeed he was easily embarrassed at the blackboard, and made a poor impression upon his teachers. It is quite possible that he did not try in the least to improve this impression. His French biographer very clearly explains his attitude:

> There was in him a hardly disguised contempt for whosoever did not bow spontaneously and immediately before his superiority, a rebellion against a judgment which his conscience challenged beforehand and a sort of unhealthy pleasure in leading it further astray and in turning it entirely against himself. Indeed, it is frequently observed that those people who believe that they have most to complain of persecution could hardly do without it and, if need be, will provoke it. To pass oneself off for a fool is another way and not the least savory, of making fools of others.

It is clear that Galois' temper was not altogether amiable, yet we should not judge him without making full allowance for the terrible strain to which he was constantly submitted, the violent conflicts which obscured his soul, the frightful solitude to which fate had condemned him.

In the course of the ensuing year, he sent three more papers to mathematical journals and a new memoir to the Académie. The permanent secretary, Fourier, took it home with him, but died before having examined it, and the memoir was not retrieved from among his papers. Thus his second memoir was lost like the former. This was too much indeed and one will easily forgive the wretched boy if in his feverish mood he was inclined to believe that these repeated losses were not due to chance but to systematic persecution. He considered himself a victim of a bad social organization which ever sacrifices genius to mediocrity, and naturally enough he cursed the hated regime of oppression which had precipitated his father's death and against which the storm

was gathering. We can well imagine his joy when he heard the first shots of the July Revolution! But alas! While the boys of Polytechnique were the very first in the fray, those of the Ecole Normale were kept under lock and key by their faint-hearted director. It was only when the three glorious days of July were over and the fall of the Bourbons was accomplished that this opportunist let his students free and indeed placed them at the disposal of the provisional government! Never did Galois feel more bitterly that his life had been utterly spoiled by his failure to become an alumnus of his beloved Polytechnique.

In the meanwhile the summer holidays began and we do not know what happened to the boy in the interval. It must have been to him a new period of crisis, more acute than any of the previous ones. But before speaking of it let me say a last word about his scientific efforts, for it is probable that thereafter political passion obsessed his mind almost exclusively. At any rate it is certain that Evariste was in the possession of his general principles by the beginning of 1830, that is, at the age of eighteen, and that he fully knew their importance. The consciousness of his power and of the responsibility resulting from it increased the concentration and the gloominess of his mind to the danger point; the lack of recognition developed in him an excessive pride. By a strange aberration he did not trouble himself to write his memoirs with sufficient clearness and to give the explanations which were the more necessary because his thoughts were more novel. What a pity that there was no understanding friend to whisper in his ear Descartes' wise admonition: "When you have to deal with transcendent questions, you must be transcendentally clear." Instead of that, Galois enveloped his thought in additional secrecy by his efforts to attain greater conciseness, that coquetry of mathematicians.

It is intensely tragic that this boy already sufficiently harassed by the turmoil of his own thoughts, should have been thrown into the political turmoil of this revolutionary period. Endowed with a stronger constitution, he might have been able to cope with one such; but with the two, how could he—how could anyone do it? During the holidays he was probably pressed by his friend, Chevalier, to join the Saint-Simonists, but he declined, and preferred to join a secret society, less aristocratic and more in keeping with his republican aspirations—the " Société des amis du peuple". It was thus quite another man who reentered the Ecole Normale in the autumn of 1830. The great events of which he had been a witness had given to his mind a sort of artificial maturity. The revolution had opened to him a fresh source of disillusion, the deeper because the hopes of the first moment had been more sanguine. The government of Louis-Philippe had promptly crushed the more liberal tendencies; and the artisans of the new revolution, who had drawn their inspiration from the great events of 1789,

soon discovered to their intense disgust that they had been fooled. Indeed under a more liberal guise, the same oppression, the same favoritism, the same corruption soon took place under Louis-Philippe as under Charles X. Moreover, nothing can be more demoralizing than a successful revolution (whatever it be) for those who, like Galois, were too generous to seek any personal advantage and too ingenuous not to believe implicitly in their party shibboleths. It is such a high fall from one's dearest ideal to the ugliest aspect of reality—and they could not help seeing around them the more practical and cynical revolutionaries eager for the quarry, and more disgusting still, the clever ones, who had kept quiet until they knew which side was gaining, and who now came out of their hiding places to fight over the spoils and make the most of the new regime. Political fermentation did not abate and the more democratic elements, which Galois had joined, became more and more disaffected and restless. The director of the Ecole Normale had been obliged to restrain himself considerably to brook Galois' irregular conduct, his "laziness," his intractable temper: the boy's political attitude, and chiefly his undisguised contempt for the director's pusillanimity now increased the tension between them to the breaking point. The publication in the "Gazette des Ecoles" of a letter of Galois in which he scornfully criticised the director's tergiversations was but the last of many offenses. On Dec. 9, he was invited to leave the school, and his expulsion was ratified by the Royal Council on Jan. 3, 1831.

To support himself Galois announced that he would give a private course of higher algebra in the backshop of a bookseller, Mr. Caillot, 5 rue de la Sorbonne. I do not know whether this course, or how much of it, was actually delivered. A further scientific disappointment was reserved for him: a new copy of his second lost memoir had been communicated by him to the Académie; it was returned to him by Poisson, four months later, as being incomprehensible. There is no doubt that Galois was partly responsible for this, for he had taken no pains to explain himself clearly. This was the last straw. Galois' academic career was entirely compromised, the bridges were burned, he plunged himself entirely into the political turmoil. He threw himself into it with his habitual fury and the characteristic intransigency of a mathematician: there was nothing left to conciliate him, no means to moderate his passion, and he soon reached the extreme limit of exaltation. He is said to have exclaimed: "If a corpse were needed to stir the people up, I would give mine." Thus on May 9, 1831, at the end of a political banquet, being intoxicated—not with wine but with the ardent conversation of an evening—he proposed a sarcastic toast to the King. He held his glass and an open knife in one hand and said simply: "To Louis-Philippe!" Of course he was soon arrested and sent to Ste. Pélagie. The lawyer persuaded him to maintain that he had actually said: "To

Louis-Philippe, *if he betray,*" and many witnesses affirmed that they had heard him utter the last words, though they were lost in the uproar. But Galois could not stand this lying and retracted it at the public trial. His attitude before the tribunal was ironical and provoking, yet the jury rendered a verdict of not proven and he was acquitted. He did not remain free very long. On the following Fourteenth of July, the government, fearing manifestations, decided to have him arrested as a preventive measure. He was given six months' imprisonment on the technical charge of carrying arms and wearing a military uniform, but he remained in Ste. Pélagie only until March 19 (or 16?), 1832, when he was sent to a convalescent home on the rue de Lourcine. A dreadful epidemic of cholera was then raging in Paris, and Galois' transfer had been determined by the poor state of his health. However, this proved to be his undoing.

He was now a prisoner on parole and took advantage of it to carry on an intrigue with a woman of whom we know nothing, but who was probably not very reputable ("une coquette de bas étage," says Raspail). Think of it! This was, as far as we know, his first love—and it was but one more tragedy on the top of so many others. The poor boy who had declared in prison that he could love only a Cornelia or a Tarpeia[2] (we hear in this an echo of his mother's Roman ideal), gave himself to this new passion with his usual frenzy, only to find more bitterness at the end of it. His revulsion is lamentably expressed in a letter to Chevalier (May 25, 1832):

> . . . How to console oneself for having exhausted in one month the greatest source of happiness which is in man—of having exhausted it without happiness, without hope, being certain that one has drained it for life?
>
> Oh! come and preach peace after that! Come and ask men who suffer to take pity upon what is! Pity, never! Hatred, that is all. He who does not feel it deeply, this hatred of the present, cannot really have in him the love of the future. . . .

One sees how his particular misery and his political grievances are sadly muddled in his tired head. And a little further in the same letter, in answer to a gentle warning of his friend:

> I like to doubt your cruel prophecy when you say that I shall not work any more. But I admit that it is not without likelihood. To be a savant, I should need to be that alone. *My heart has revolted against my head.*[3] I do not add as you do: It is a pity.

Can a more tragic confession be imagined? One realizes that there is no question here of a man possessing genius, but of genius possessing a man. A man? a mere boy, a fragile little body divided within itself by disproportionate forces, an undeveloped mind crushed merci-

[2] He must have quoted Tarpeia by mistake.

[3] The italics are mine.

lessly between the exaltation of scientific discovery and the exaltation of sentiment.

Four days later two men challenged him to a duel. The circumstances of this affair are, and will ever remain, very mysterious. According to Evariste's younger brother the duel was not fair. Evariste, weak as he was, had to deal with two ruffians hired to murder him. I find nothing to countenance this theory except that he was challenged by two men at once. At any rate, it is certain that the woman he had loved played a part in this fateful event. On the day preceding the duel, Evariste wrote three letters of which I translate one:

May 29, 1832.

Letter to all Republicans.

I beg the patriots, my friends, not to reproach me for dying otherwise than for the country.

I die the victim of an infamous coquette. My life is quenched in a miserable piece of gossip.

Oh! why do I have to die for such a little thing, to die for something so contemptible!

I take heaven to witness that it is only under compulsion that I have yielded to a provocation which I had tried to avert by all means.

I repent having told a baleful truth to men who were so little able to listen to it coolly. Yet I have told the truth. I take with me to the grave a conscience free from lie, free from patriots' blood.

Goodbye! I had in me a great deal of life for the public good.

Forgiveness for those who killed me; they are of good faith.

E. Galois.

Any comment could but detract from the pathos of this document. I will only remark that the last line, in which Galois absolves his adversaries, destroys his brother's theory. It is simpler to admit that his impetuosity, aggravated by female intrigue, had placed him in an impossible position from which there was no honourable issue, according to the standards of the time, but a duel. Evariste was too much of a gentleman to try to evade the issue, however trifling its causes might be; he was anxious to pay the full price of his folly. That he well realized the tragedy of his life is quite clear from the laconic postscriptum of his second letter: *Nitens lux, horrenda procella, tenebris aeternis involuta.* The last letter addressed to his friend, Auguste Chevalier, was a sort of scientific testament. Its seven pages, hastily written, dated at both ends, contain a summary of the discoveries which he had been unable to develop. This statement is so concise and so full that its significance could be understood only gradually as the theories outlined by him were unfolded by others. It proves the depth of his insight, for it anticipates discoveries of a much later date. At the end of the letter, after requesting his friend to publish it and to ask Jacobi or Gauss to pronounce upon it, he added: "After that, I hope some people will find it profitable to unravel this mess. *Je t'embrasse avec*

effusion." The first sentence is rather scornful but not untrue and the greatest mathematicians of the century have found it very profitable indeed to clear up Galois' ideas.

The duel took place on the 30th in the early morning, and he was grievously wounded by a shot in the abdomen. He was found by a peasant who transported him at 9:30 to the Hôpital Cochin. His younger brother—the only member of the family to be notified—came and stayed with him, and as he was crying, Evariste tried to console him, saying: "Do not cry. I need all my courage to die at twenty." While still fully conscious, he refused the assistance of a priest. In the evening peritonitis declared itself and he breathed his last at ten o'clock on the following morning.

His funeral, which strangely recalled that of his father, was attended by two to three thousand republicans, including deputations from various schools, and by a large number of police, for trouble was expected. But everything went off very calmly. Of course it was the patriot and the lover of freedom whom all these people meant to honour; little did they know that a day would come when this young political hero would be hailed as one of the greatest mathematicians of all time.

A life as short yet as full as the life of Galois is interesting not simply in itself but even more perhaps because of the light it throws upon the nature of genius. When a great work is the natural culmination of a long existence devoted to one persistent endeavour, it is sometimes difficult to say whether it is the fruit of genius or the fruit of patience. When genius evolves slowly it may be hard to distinguish from talent,—but when it explodes suddenly, at the beginning and not at the end of life, or when we are at a loss to explain its intellectual genesis, we can but feel that we are in the sacred presence of something vastly superior to talent. When one is confronted with facts which can not be explained in the ordinary way, is it not more scientific to admit our ignorance than to hide it behind faked explanations? Of course it is not necessary to introduce any mystical idea, but it is one's duty to acknowledge the mystery. When a work is really the fruit of genius, we cannot conceive that a man of talent might have done it "just as well" by taking the necessary pains. Pains alone will never do; neither is it simply a matter of jumping a little further, for it involves a synthetic process of a higher kind. I do not say that talent and genius are essentially different, but that they are of different orders of magnitude.

Galois' fateful existence helps one to understand Lowell's saying: "Talent is that which is in a man's power, genius is that in whose power man is." If Galois had been simply a mathematician of considerable ability, his life would have been far less tragic, for he could have used

his mathematical talent for his own advancement and happiness; instead of which, the furor of mathematics—as one of his teachers said—possessed him and he had no alternative but absolute surrender to his destiny.

Lowell's aphorism is misleading, however, for it suggests that talent can be acquired, while genius cannot. But biological knowledge points to the conclusion that neither is really acquired, though both can be developed and to a certain extent corrected by education. Men of talent as well as men of genius are born, not made. Genius implies a much stronger force, less adaptable to environment, less tractable by education, and also far more exclusive and despotic. Its very intensity explains its frequent precocity. If the necessary opportunities do not arise, ordinary abilities may remain hidden indefinitely; but the stronger the abilities the smaller need the inducement be to awaken them. In the extreme case, the case of genius, the ability is so strong that, if need be, it will force its own outlet.

Thus it is that many of the greatest accomplishments of science, art and letters were conceived by very young men. In the field of mathematics, this precocity is particularly obvious. To speak only of the two men considered in this essay, Abel had barely reached the age of twenty-two and Galois was not yet twenty, perhaps not yet nineteen, when they made two of the most profound discoveries which have ever been made. In many other sciences and arts, technical apprenticeship may be too long to make such early discovery possible. In most cases, however, the judgment of Alfred de Vigny holds good. "What is a great life? It is a thought of youth wrought out in ripening years." The fundamental conception dawns at an early age—that is, it appears at the surface of one's consciousness as early as this is materially possible—but it is often so great that a long life of toil and abnegation is but too short to work it out. Of course at the beginning it may be very vague, so vague indeed that its host can hardly distinguish it himself from a passing fancy, and later may be unable to explain how it gradually took control of his activities and dominated his whole being. The cases of Abel and Galois are not essentially different from those contemplated by Alfred de Vigny, but the golden thoughts of their youth were wrought out in the ripening years of other people.

It is the precocity of genius which makes it so dramatic. When it takes an explosive form, as in the case of Galois, the frail carcass of a boy may be unable to resist the internal strain and it may be positively wrecked. On the other hand when genius develops more slowly, its host has time to mature, to adapt himself to his environment, to gather strength and experience. He learns to reconcile himself to the conditions which surround him, widely different as they are, from

those of his dreams. He learns by and by that the great majority of men are rather unintelligent, uneducated, uninspired, and that one must not take it too much to heart when they behave in defiance of justice or even of common sense. He also learns to dissipate his vexation with a smile or a joke and to protect himself under a heavy cloak of kindness and humour. Poor Evariste had not time to learn all this. While his genius grew in him out of all proportion to his bodily strength, his experience and his wisdom, he felt more and more ill at ease. His increasing restlessness makes one think of that exhibited by people who are a prey to a larvate form of a pernicious disease. There is an internal disharmony in both cases, though it is physiological in the latter, and psychological in the former. Hence the suffering, the distress and finally the acute disease or the revolt!

A more congenial environment might have saved Galois. Oh! would that he had been granted that minimum of understanding and sympathy which the most concentrated mind needs as much as a plant needs the sun! . . But it was not to be; and not only had he no one to share his own burden, but he had also to bear the anxieties of a stormy time. I quite realize that this self-centered boy was not attractive—many would say not lovable. Yet I love him; I love him for all those who failed to love him; I love him because of his adversity.

His tragic life teaches us at least one great lesson: one can never be too kind to the young; one can never be too tolerant of their faults, even of their intolerance. The pride and intolerance of youth, however immoderate, are excusable because of youth's ignorance, and also because one may hope that it is only a temporary disorder. Of course there will always be men despicable enough to resort to snubbing, as it were, to protect their own position and to hide their mediocrity, but I am not thinking of them. I am simply thinking of the many men who were unkind to Galois without meaning to be so. To be sure, one could hardly expect them to divine the presence of genius in an awkward boy. But even if they did not believe in him, could they not have shown more forbearance? Even if he had been a conceited dunce, instead of a genius, could kindness have harmed him? . . . It is painful to think that a few rays of generosity from the heart of his elders might have saved this boy or at least might have sweetened his life.

But does it really matter? A few years more or less, a little more or less suffering. . . . Life is such a short drive altogether. Galois has accomplished his task and very few men will ever accomplish more. He has conquered the purest kind of immortality. As he wrote to his friends: "I take with me to the grave a conscience free from lie. free from patriot's blood". How many of the conventional heroes of history, how many of the kings, captains and statesmen could say the same?

MARS AS A LIVING PLANET

By G. H. HAMILTON
LOWELL OBSERVATORY, FLAGSTAFF, ARIZONA

IN contradistinction to the Moon as a *dead* world, I can speak of Mars and the Earth as *living* planets.

It is the purpose of this paper to present observational evidence to show that Mars has an atmosphere and is imbued with a considerable degree of warmth—that the changes observed upon its surface would necessitate such an atmosphere, in fact that the planet approaches the conditions that we know upon the Earth, even if it does not quite attain them.

To approximate the unchangeableness and sterility seen on the Moon—because of its lack of atmosphere and the intense cold due to its long night—it would be necessary here on Earth to resort to a vacuum or other preservatives. A similar condition on Mars is inconceivable from what we know of its surface features and the changes which have occurred in them from the earliest reliable observations. Disintegration and growth depend, not only on the action produced by atmosphere but also on the presence of organisms. It is true that inorganic material suffers change from mechanical and chemical action, but this again admits water and atmosphere into the consideration of its cause.

CLOUD OVER SOUTHERN PORTION OF SYRTIS MAJOR

1903 1920

June 1 May 26
P. L. G. H. H.

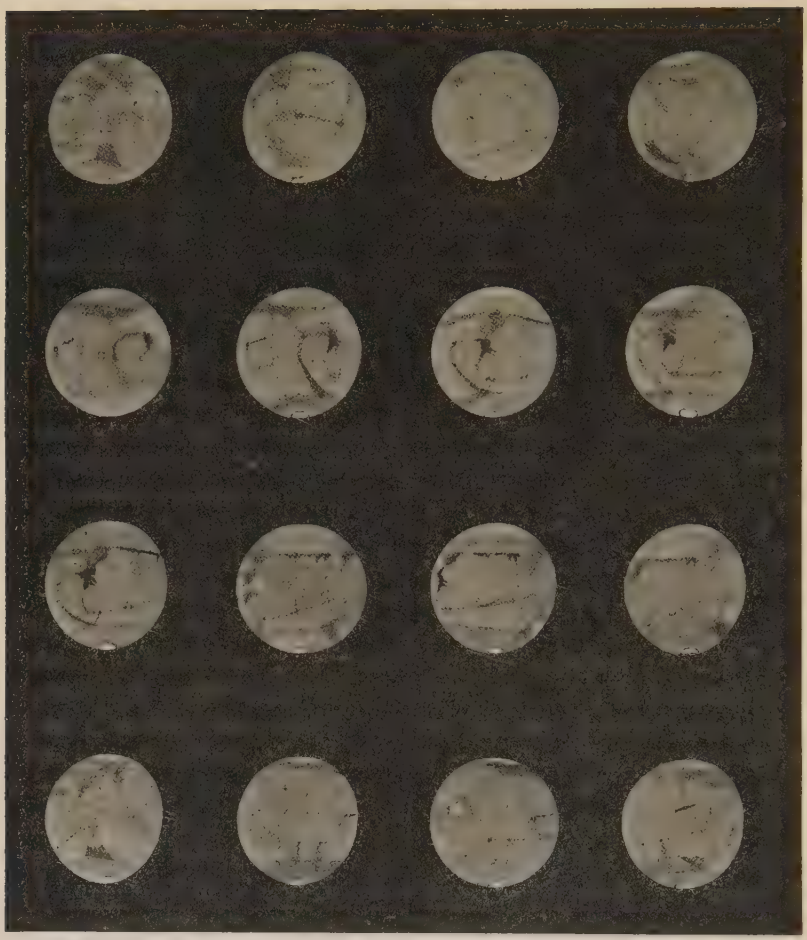
The germination and gemination of the canals from the time of Schiaparelli show an unaccountable seasonal change, if we are to believe in a cold as intense as that which some people have suggested exists, or an atmosphere so thin that it would be lacking in those gases commonly supposed necessary for the support of organic material. One would hardly suppose that an atmosphere sufficiently dense to produce mechanical changes to the extent that they have been observed in inorganic matter, would have little or no effect in the production of organisms.

The dependence of the canals on the seasons of Mars for their visibility established by Lowell, and the variations in the dark areas are confirmatory evidence of an atmosphere; for these changes would be inexplicable on any object, most certainly a planet, placed in a refrigerator or vacuum bell.

There were, at this opposition, two regions on the planet where a considerable haze existed; this was very evident near either limb, but when these regions were on or near the center of the disk the haze was only noticeable by its diffusing and dimming effect on the surface markings. It appeared to cover the Syrtis Major and its surroundings, and also a region opposite—about the Lacus Lunae south of the Mare Acidalium. Detail outside of these regions was usually clear cut.

When on the limb or terminator, i. e., near sunrise or sunset, the haze above these regions seemed to condense and became itself visible in the form of a dull blue-white covering very easily seen on account of the contrast of this color to that of the surrounding desert or dark areas over which it appeared to hang. These condensations in the haze remained of a nearly constant area close up to the terminator, and remained close to the terminator during the time that they lasted. In consequence those areas of the planet coming onto the disk from the terminator or leaving the disk, appeared from behind this covering or disappeared under it in a remarkable manner. The change in formation of these blue-white areas was of a character that one would expect if it had been atmospheric and cloud-like in nature. It was decidedly an evening and morning effect. The shift of the surface of the planet with respect to these apparent clouds was incompatible with the assumption that they belonged to the surface, but pointed expressly to the fact that they were above the surface and atmospheric.

This article is illustrated by two plates. The first shows two drawings, one made in 1903 by Dr. Lowell, the other in 1920, by myself. Dr. Lowell's drawing of June 1, 1903, depicts a season, for that region on Mars, corresponding on our Earth to August 6. It is interesting to note that my drawing of May 26, 1920, shown with his, corresponds in season to about August 13. It will be noticed that though a period of seventeen years has elapsed, the cloud formation is very similar over



MARS 1920

Mar. 8	Mar. 5	May 11	May 11
$\lambda =$ 34	$\lambda =$ 63	$\lambda =$ 127	$\lambda =$ 91
Apr. 28	May 26	May 24	May 26
$\lambda =$ 250	$\lambda =$ 262	$\lambda =$ 305	$\lambda =$ 308
May 22	Apr. 13	May 24	June 21
$\lambda =$ 312	$\lambda =$ 344	$\lambda =$ 342	$\lambda =$ 1
June 21	June 5	May 7	June 4
$\lambda =$ 51	$\lambda =$ 168	$\lambda =$ 166	$\lambda =$ 211

George Hall Hamilton.

$\lambda =$ Longitude of Central Meridian at time of drawing.

the Syrtis at approximately the same season. The drawings, of course, have only been used in comparison for this particular feature.

The second plate, made up of sixteen selected drawings, not only shows the curious cloud formation over the Syrtis Major and the Mare Acidalium, but also gives one a complete view of the Martian surface except that portion near the southern pole which was continuously turned away from us at this opposition.

It will be noticed from these drawings that both the Syrtis and the Mare Acidalium are nearly completely free from cloud when on the center of the disk, but that they are covered by cloud to a great extent when near the limb or terminator.

The drawings, which are typical of all those made at this opposition, show unmistakeable evidence of a considerable atmosphere. This can not be wondered at when one realizes the amount of water vapor transported from one pole to the other each Martian half-year: it is an atmosphere quite capable of being, in fact, a mechanical transferer of this material from pole to pole.

That Mars is a living planet seems certain from these changes that are seen to continually take place on its surface and above the ground. The dark areas and canals are seemingly, at least in part, organic. The polar caps by their disappearance and reappearance each year, imply *both mechanical and physical* change, as do also the daily variations in the cloud formations.

How far organic evolution has progressed it would be hard to tell, but that there is a succession of seasons on Mars as on the Earth, and consequent germination is evident.

THE PROGRESS OF SCIENCE

SCIENTIFIC MEETINGS

We are able to print in the present issue of THE SCIENTIFIC MONTHLY extracts from addresses given at the meeting of the British Association held at Edinburgh from September 7 to 14. The meeting is in progress as this journal goes to press, and practically nothing from England regarding its proceedings has been cabled. The addresses of the president of the association and of the presidents of the sections are usually the best summaries of the progress of science prepared each year, and the English newspapers and journals have been in the habit of paying much more attention to them than is the case in this country with the corresponding addresses of the American Association. This more general attention naturally causes the preparation of addresses of greater interest, which in turn leads to their more widespread publication to the advantage of science and of the national welfare.

The American Association meets this year at Toronto, and the meeting should be of more than usual interest. Dr. L. O. Howard, chief of the Bureau of Entomology of the Department of Agriculture, who gives the address of the retiring president, is master of a subject of great scientific and economic concern, and it is desirable that his address and the addresses of the vice-presidents and the other proceedings of more than technical interest should be given wide publicity. It is to be hoped that the recently organized Science Service may be of use in this direction. Two distinguished English men of science have been invited to Toronto as guests of the association, one in the biological and one in the physical sciences, and Professor Bateson has consented to be present.

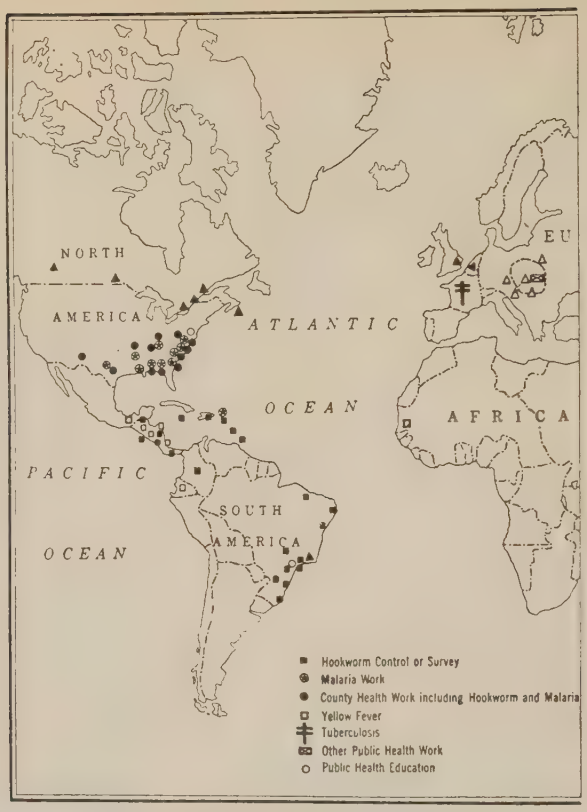
At the same time as the meeting of the British Association in Edinburgh, the chemists have been holding Anglo-American meetings. The British Society of Chemical Industry met with the Canadian Branch in Montreal under the presidency of Sir William Pope, professor of chemistry in the University of Cambridge. After visits to Ottawa and Toronto, the English and Canadian chemists joined in the New York meeting of the American Chemical Society. The number was small, but they were admirably represented by their president, who took part in the international program and made an address at the dinner. The American Chemical Society was also fortunate in its president, Dr. Edgar Fahs Smith, provost emeritus of the University of Pennsylvania, who first held the office twenty-five years ago. In his presidential address, in his address at the dinner and at the meetings on educational chemistry and the history of chemistry, Dr. Smith did much to emphasize the broader aspects of the science.

In the attendance and on the programs, industrial and engineering chemistry were largely represented. Much interest was manifested in the embargo on German chemicals and in the Chemical Warfare Service. There were elaborately arranged excursions to industrial plants in and around New York City and during the week following the meeting a large national exposition of Chemical Industries was held in one of the armories of the city.

Following the meeting of the chemists an International Congress of Eugenics is being held in New York City. While the time has scarcely come when international congresses can be held and while eugenics ap-

Photograph by Underwood and Underwood.

SIR WILLIAM POPE
President of the Society of Chemical Industry

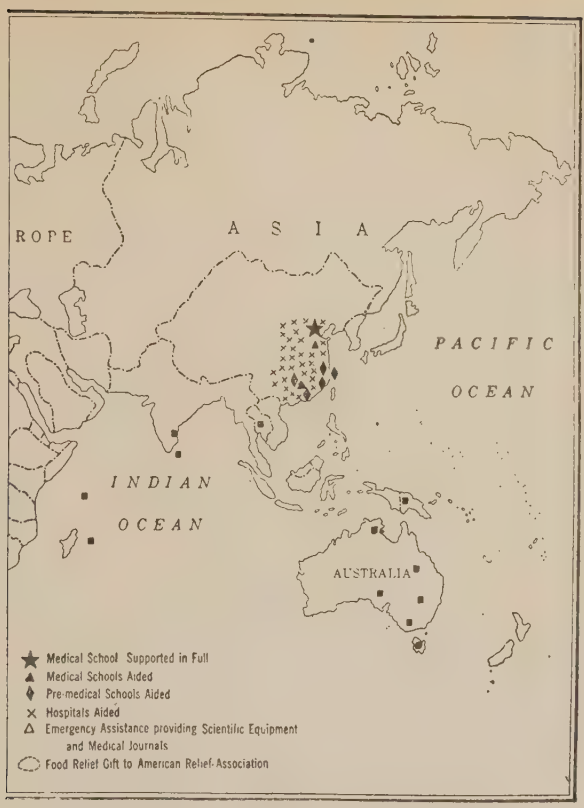


MAP SHOWING WORLD-WIDE ACTIVITIES

pears to be still an amateur science, mainly promoted by amateurs, the meeting promises to be of interest. The program gives prominence to genetics which has become a real science in which America may perhaps claim leadership. At the opening meeting addresses were announced by Dr. Henry Fairfield Osborn, president of the congress and of the American Museum of Natural History; Major Leonard Darwin, president of the Eugenics Education Society, London; and Dr. Charles B. Davenport, director of the Department of Genetics of the Carnegie Institution. Among those from abroad who make addresses before the sections are M. Lucien Cuénot, Nancy, France; Professor Herman Lundborg, Upsala, Sweden, and M. Georges Vacher de Lapouge, Poitiers, France.

THE ACTIVITIES OF THE ROCKEFELLER FOUNDATION

The president of the Rockefeller Foundation, Dr. George E. Vincent, has issued a popular review of the work carried out during the year 1920, which gives a good idea of its magnitude and wide influence in aid of medical education and in the field of public health. A map of the world showing the widespread distribution of the various activities of the foundation is here reproduced. The total endowment now amounts to over 174 million dollars, and during the year approximately seven million dollars have been spent in carrying out the program of the foundation. Of this amount, over two million dollars were contributed for the improvement of the public health in various



OF THE ROCKEFELLER FOUNDATION

parts of the world, especially towards the eradication of hookworm, malaria and yellow fever, and the establishment of adequate institutions for the training of public health officials. Over $300,000 was given to the School of Hygiene and Public Health of the Johns Hopkins University.

In its second great field of endeavor, that of improving the standards of medical education, the foundation has expended nearly four and a half million dollars during the year. The greater part of this sum has been used for the building and equipment of a medical school in China, the Peking Union Medical College, and to aid other schools already established in that country. Substantial sums have been pledged to the University College Hospital in London—a total of about five million dollars, to be equally divided between buildings and endowments for increased education and research facilities. In addition, aid has been given to a number of schools in this country and in Canada.

The foundation has contributed to the support of a number of humanitarian and charitable organizations, including the appropriation of a million dollars to the child-feeding fund of the American Relief Administration, and to various miscellaneous enterprises having for their object the stimulation of research and the improvement of the medical standards of the world.

The report indicates that good progress is being made in the aim of the Rockefeller Foundation to increase the common store of knowledge of the causes of disease, and through demonstrations and the ser-

vices of trained experts to diffuse this information as widely as possible among all peoples.

THE HARVARD SCHOOL OF PUBLIC HEALTH

Plans for the organization of a School of Public Health in Harvard University, with the aid of an initial gift of $1,785,000 by the Rockefeller Foundation, are announced by the university and the officers of the foundation. The announcement says that an excellent general course for the training of public health officers as well as special courses in preventive medicine, in tropical medicine and industrial hygiene have already been developed at Harvard. The work has been hampered, however, by lack of adequate funds and by uneven growth.

The new school will provide opportunities for research, will unify existing courses and will offer new or extended teaching facilities in public health administration, vital statistics, immunology, bacteriology, medical zoology, physiological hygiene and communicable diseases.

For the housing of the school the university hopes to secure an existing building of very suitable character immediately adjacent to the Medical School. Funds for the purchase and equipment of the building will be drawn from the gift of the Rockefeller Foundation. The cost of maintenance and development of the school will be met from endowment funds in part set aside by the university and in part contributed by the Foundation. The Foundation's immediate appropriations to the project will aggregate $1,785,000. The arrangement also provides for further gifts, if the growth of the school seems to demand it, to any amount which shall not exceed $500,000.

Though the School of Public Health at Harvard will have its headquarters in a well-equipped building of its own and have its own separate faculty and administration, it will be developed in close relation with other divisions of the university, especially the Medical School. The administration buildings of the two schools will, it is hoped, stand side by side on the same grounds; certain heads of departments will be members of both faculties; and a number of laboratories and lecture rooms will be used in common.

The school will be able to cooperate with a large number of laboratories, hospitals and public health agencies in Boston and thus afford its students unusual opportunities for first-hand investigation and practical field experience. In addition, the school, through cooperative relations with a number of manufacturing and commercial corporations, will be able to offer the students practical experience in industrial hygiene.

SCIENTIFIC ITEMS

We record with regret the death of Joel Asaph Allen, curator of the Department of Birds and Mammals at the American Museum of Natural History; of George Trumbull Ladd, for forty years professor of moral philosophy and metaphysics at Yale University; and of Peter Cooper Hewitt, the electrical and mechanical engineer of New York City.

On July 21, a memorial was unveiled in the public gardens at Dartmouth to the memory of Thomas Newcomen, the pioneer of the steam engine. Newcomen was born in Dartmouth in 1663; he followed the trade of blacksmith there, and was also a Baptist preacher.

The John Burroughs Memorial Association has been inaugurated at a meeting of a number of his friends at the American Museum of Natural History, the immediate purpose of the association being to protect Mr. Burroughs' home and camps and to preserve them, with their wild life, for future generations.

THE SCIENTIFIC MONTHLY

NOVEMBER, 1921

THE SECOND INTERNATIONAL CONGRESS OF EUGENICS[1]

THE FIELD OF EUGENIC REFORM

By Major LEONARD DARWIN

THE section of which this is the opening meeting deals with eugenics in relation to the state, to society and to education; it may be described as the section for applied genetics. I have been tempted to describe it as the section for practical eugenics; but that description would hardly be appropriate. The details of experimentation and research fall outside our sphere; but to make experiments is the most practical thing one can do. Your practical manufacturer knows full well that if he trusted to running forever on the old lines he would soon come to grief. We are, therefore, here dealing with the practical application of knowledge acquired by practical research.

Differences of opinion no doubt exist amongst those who have conducted the researches on which we have to build our practical superstructure; differences both as to methods and as to results. Even more marked differences are, however, sure to be felt in this section, where we have to apply to human conduct the knowledge acquired by others. Ought this to alarm us? I think not. I remember long ago seeing a picture in our English *Punch* in which a tailor is depicted when making excuses for some misfit as saying, "You must remember, sir, that tailoring has not yet been reduced to the level of one of the exact sciences." My views about eugenics are somewhat similar, though that is not the way I should express them. But we must remember that, as evolutionary science teaches us, uniformity always means stagnation. If we all felt alike, no one of us could ever pick up from a neighbor any wiser thoughts than his own; and we should therefore neither regret a certain amount of divergence of opinion nor attempt to hide it. If the beasts of the field had never fought together in the struggle for existence, mankind would never have been developed out of our ape-

[1] Held at the American Museum of Natural History, New York City, from September 22 to 28, 1921.

like ancestors. But do not mistake me. I am not advocating war, which is the most damnable thing on earth both as to its immediate and its racial consequences. We must obtain the benefits which did result from savage warfare in some other way; but competition we must have in everything, our opinions included. If any other eugenist should disagree entirely with my assertions, I shall feel in no way hurt!

But what is the foundation on which we, in this section, have to build? As I have already stated in this room, I hold that our aim as eugenists should be to increase the rate of multiplication of stocks above the average in hereditary qualities and to decrease it amongst the less fit. Others may wish to make our efforts cover a wider field, holding, for example, that the immediate benefits likely to arise from the teaching of sex hygiene should be included. With such as these I shall not quarrel for I am in full sympathy with their aims. But I do think that as a matter of convenience it would be as well to restrict the meaning of "eugenics" so as to make it cover no more than was intended by Sir Francis Galton who coined the word, that is, that it should apply only to measures affecting the inborn qualities of future generations.

Now as to the differences of opinion amongst us, I am glad to think that we are not divided into definitely antagonistic camps; for all are, as it were, linked together by the existence of every intermediate shade of opinion. No doubt at one end of the scale there are eugenists who regard racial progress as an assured law of nature, a progress merely to be hastened by the elimination of certain extremely undesirable types, such as the insane, the feeble-in-mind, and those endowed with grossly defective inborn constitutions. At the other end of the scale are those who regard the signs of the times as pointing without doubt to a slow and progressive deterioration in the innate qualities of all civilized peoples; that is, to national degradation, which it will only be possible to arrest by national efforts covering a wide field of endeavor. In short, though all eugenists aim at improving the inborn qualities of posterity, yet some would attack on a wider front than others. In this connection it may be convenient also to divide inborn qualities into two groups; groups which also can not be separated from each other by any very definite line of demarcation. At one end of the series we have qualities dependent on a single something which the child received before its birth from its parents, whilst qualities at the other end of the series depend on a large number of such somethings; just as we may divide tables into those which have one leg and those which have many supports. In technical language, the distinction here suggested for consideration is that between qualities dependent on a single Mendelian factor—or let us say on one or but few such factors—and qualities dependent on large numbers of factors. The qualities belonging to these two groups demand somewhat different treatment,

and some eugenists attach more importance to the one group and some to the other.

Let us first consider the single factor qualities—the one legged tables—in cases where such qualities are harmful; and let us take as a single example a deformity called brachydactyly, the symptoms of which are the fingers being excessively short. Now a child before its birth either has or has not been endowed with the factor resulting in this ailment. If it has not, it will not show these symptoms, and there is an end of the matter. If it has been so endowed, it is certain to have its hands crippled in this way, and it is, moreover, certain to pass on this deformity to many of its offspring. How the factor first arose in the ancestry of the brachydactylous child is unknown; but its apparently spontaneous appearance is at all events such a rare event that for practical purposes it may be neglected. This is the very simplest eugenic problem with which we have to deal; for if we could prevent parenthood in the case of all brachydactylous persons, we might thus stamp out this ailment forever. The matter is not often quite as simple as this; for, in regard to many defects, the child must receive the harmful endowment from *both* parents in order to be harmed thereby. If the endowment be received from one parent only, its recipient is apparently normal; but all the same he is the carrier of this hidden evil, very likely to be passed on to future generations, and to show its harmful effects when it chances to be combined in one individual with a similar endowment from another line of descent. Here also all that can be done is to prohibit parenthood in the case of all those who, by exhibiting the symptoms in question, show that they have the double dose of defective heredity; though here the beneficial effects will be more slowly obtained. In both cases all that has to be decided is whether the defect in the present and in all future generations constitutes an injury sufficiently grave to justify, *in this one generation only,* the actual prevention of parenthood or the self-sacrifice needed for its voluntary abandonment. The world could be freed from all such ailments more less quickly, and it is only a question in each case whether it is worth the cost of thus freeing it. But please note—and this is the point to which I especially wish to call your attention—if we were to rid the world of any one of these single-factor hereditary effects we should probably thus benefit mankind in no other respect.

Here I cannot refrain from saying a few words about the feeble-in-mind; though to do so is in a measure to depart from the thread of my argument. Whatever may be the final verdict of science as to the nature of the factors on which this grave evil depends, all experts now agree that it should be treated in the way in which single factor qualities should be dealt with; that is to say, each case should be studied separately and dealt with on its individual merits. Here in the United

States you have at least three hundred thousand or four hundred thousand of these unfortunates, and the numbers would probably be far greater if high grade cases were to be included. A very large proportion of the mental defectives who become parents will pass on this ailment to many of their children; whilst many of their offspring, though apparently normal themselves, will be endowed with the power of transmitting this to their descendants; and, if the interests of posterity are not to be grossly neglected, no feeble-minded person should be allowed to become a parent. Moreover, those who have studied the problem, all of them, I believe, agree that the right method to adopt is, as a rule, segregation; by which is meant confinement in comfort, the sexes being kept apart. We all hate interfering with liberty; but let it always be remembered that liberty necessitates equality, and that as equality is impossible with the feeble-in-mind, they can under no circumstances ever have true liberty. Segregation is unquestionably the kindest course to adopt in most cases, especially when all the natural protectors of the afflicted have disappeared. The creation of the necessary accommodations would present difficulties, but it would be a national economy in the long run.

There is, however, one difficulty to be faced which some eugenists have passed over too lightly. The feeble-in-mind often attract to themselves far more affection than would be expected by the inexperienced, and in nearly all cases the mother has strong instinctive sentiments in regard to her children. The removal of the mentally defective infant from its home is in consequence often keenly resented; a resentment which may no doubt frequently be overcome by argument, except when it is backed up by less reputable desires dependent on the possible economic advantages to the family. Here is a difficulty which must by no means be neglected; though in my country at all events, what is now greatly needed is to make the segregation of the mentally defective more easy, not more difficult, than it is at present. Now these conflicting considerations have forced me to consider what part sterilization could be made to play in the eugenic program. It is not for me to discuss what has been done in this respect in the United States; for there are many present who can deal with this topic better than I can. I am aware that the American Breeders Association has investigated this subject with care, and I wish to urge as strongly as I possibly can that a continuation of these scientific researches is the most practical thing that can now be done. We want to know what is the best method of sterilization, and what are all the objections to it. Is the X-ray method to be relied on? What effect would it have on the offspring if insufficiently applied to produce sterility? Is there any danger of cancer as a result? I strongly press this inquiry with regard to X-rays because I think that the adoption of surgical methods does

increase the prejudice against sterilization, especially in regard to the operation needed for women. The prejudice itself is very likely to be instinctive; for natural selection is almost certain to have eliminated all mental traits which are opposed to procreation. If this be so, this is a prejudice certain to be met with, and only to be overcome by reason.

If a sufficiently safe method of sterilization is available for both sexes as some experts now hold to be actually the case, would it not be a useful auxiliary to segregation? Mentally defective persons ought to be allowed to live at home, or boarded out where they can be useful provided that ample precautions are taken to make it certain that they can thus be maintained in equal contentment to when living in an institution, that all other conditions are suitable, and that procreation will be very improbable. Might not voluntary sterilization be regarded as a strong plea in favor of permission being given by the authorities for the mentally defective person not to be taken to an institution? Many parents would, I believe, gladly welcome this alternative, if carefully explained, in order to retain their child under their own care; though here again it should be ascertained that the home conditions are all suitable. No doubt sterilization may in some cases facilitate immorality; but if the authorities were given power to enforce segregation in the case of all sterilized persons found to be living an immoral life, the harmful consequences might be largely diminished. I am myself inclined to favor the introduction of sterilization as a voluntary and experimental measure; for if it proved to be successful, its use would certainly be extended, its racial advantages being obvious.

To revert to my main theme, we have seen that as regards such bad qualities as are dependent on one or but few mendelian factors, the right course to adopt is to consider and to deal with each case separately; and this is no doubt the way in which many eugenists wish to treat all such human qualities as need be considered. Probably we shall all agree that the grossly unfit whether they be habitual criminals, utterly incorrigible wastrels, or those endowed with excessively bad natural constitutions, ought not to be allowed to become parents, each individual being separately weighed in the balance. But most of the bad qualities leading to gross unfitness are dependent on many factors, and what I now wish to suggest for your consideration is that the recognition of this fact ought to make us modify in certain respects the policy which we recommend for adoption. To make the point clear it will be better to turn to the consideration of good qualities and to study the methods of increasing the rate of multiplication of those well endowed by nature. No single good qualities known to me can be certainly attributed to the presence of a single factor; and if we consider the make-up of a man of genius, including reasoning power,

concentration of mind, energy, perseverance, faculty of observation, et cetera, et cetera, we may feel sure that many factors are involved. Almost every student of eugenics has at some time or other during his career attempted to sketch out schemes for the individual selection of a number of highly endowed persons, for inducing them to marry superior mates, and for the encouragement of the production of large families by these selected couples. Ought we not, therefore, to inquire to what extent reliance is to be placed on such methods when the qualities involved are dependent on many factors? The matter is complicated; but as it is one to which I am very anxious that the attention of eugenists should be directed, I beg for your patience whilst I try to illustrate the point in question.

If a few millionaires were to be selected, and all their wealth were to be distributed broadcast amongst the people, we may be certain that the result would be a feeling of keen disappointment amongst the originators of the plot, for each recipient would receive such a minute share of the booty. Again, if it were possible to create a few millionaires, wealth and all, and if generation after generation, their descendents were to dissipate this newly created wealth until it was widely scattered throughout the whole land, in this case also the ultimate benefits to the mass of the people would be very small. Now the eugenist who wishes to see a number of eminent persons picked out and induced to produce large families is no doubt aiming at what would be equivalent to the creation of a number of distinguished persons in the coming generations; and I do not doubt that at all events as regards the next generation only, a marked success in this respect could thus be reaped. But we have seen that the good qualities of the selected parents would be due to many factors; and these factors, like the money of the spendthrift descendants of our millionaire would tend to become more and more widely scattered amongst the people in accordance with an inevitable law of nature; the final result being, we may be equally certain, very disappointing to the eugenist, as far as ultimate racial results are concerned. If we want more millionaires—I am not saying whether we do or do not—one way to secure their presence in greater numbers in the future would be to raise the level of the wealth of the whole people; for the more we were to enrich the soil of any country, as it were, by increasing its total wealth, the greater would be the number of its inhabitants who would in the ordinary course of trade grow so rich as to become millionaires. In nearly the same way, if we want more persons eminent in morals, intellect, or physical strength to spring into existence in all the generations to come, the most certain method of achieving this result would be to raise the level of the whole people in regard to their inborn qualities. For if this could be done, the factors needed for the production of a

man of genius would exist in greater numbers; their union by chance in any one individual, or the actual appearance of a genius, would occur very often; whilst all the while the mass of the people would be receiving the benefits due to their improved natural endowments. Surely this then is a policy not to be neglected.[1]

The effects of the wide distribution of a millionaire's wealth, even though disappointing to those concerned, yet if accepted as an illustration of the racial consequences of increasing the progeny of a number of selected persons, certainly give a greatly exaggerated idea of the benefits thus to be obtained; and we must seek for some more accurate method of attempting to estimate the probable results. Sir Francis Galton stated that one man in 4,000 might be fairly described as being "eminent" in intellect; and we may perhaps in like manner describe the tallest of a group of 4,000 men as being eminent in stature. Now Frederick the Great is said to have picked out the biggest men he could lay hands on, and then to have mated them by no gentle means to very tall women,[2] with the object of securing a number of huge recruits in the coming generation. To what extent the royal aspirations were fulfilled in this respect I do not know. But let us follow Frederick's example in imagination and consider what would be the effect of such a scheme on the average height of the people in future generations. In a town of 8,000 inhabitants there would probably be one man and one woman eminent in stature and let us imagine that we bring these two together, with the result that two more children

[1] The analogy of the inheritance of money is, of course, faulty in many respects. With natural inheritance the chances of a person receiving a good endowment from his parents are the same whether he has few brothers and sisters or many. Again, many have no money to leave to their descendants, and often money is only received from one parent. With natural inheritance every one is certain to receive an endowment, good or bad, from each parent, and one endowment is as important as the other. Lastly, whilst we can aim at a more even distribution of wealth, it would be impossible, even if we would, to prevent the fortuitous coming together of the necessary factors so as to produce a man of genius.

[2] Frederick would have produced nearly the same ultimate results on the race if he had allowed his male and female giants to marry whom they liked provided their progeny increased. It has not been sufficiently recognized that, putting aside the effects of assortive mating, the only racial advantages of *mating* the selected individuals are (a) the immediate production of giants, for example, and (b) that greater results can perhaps thus be obtained for the same money, as one stimulus then affects two selected individuals. It should also be noted that if in consequence of their selection the selected persons were moved out of a more fertile into a less fertile stratum of society, and if their descendants remained in that less fertile stratum, then the ultimate results would be dysgenic, whatever might be the more immediate consequences. In these circumstances thus to create an improved type in perpetuity would necessitate the establishment of a rigid caste system.

are brought into the world than would be the case if we had not interfered. Looking to the male part of the population only—for simplicity and not out of disrespect to the female half—we should find that our tall man was rather under nine inches in height above the average; and, as a rough approximation to the truth, we may imagine that after many generations these nine inches would become evenly distributed amongst the whole male population of the town; or, in other words, that we should thus have raised the average stature of that town by a little more than one five-hundredth part of an inch.[3] If this be a true conclusion, as I believe it to be, you may judge that if you were to pick out the 12,500 tallest men and 12,500 tallest women in each generation in the United States, if you were to mate them together and if somehow or other you were to induce each couple to have two *additional* children, you would thus in about 1,500 years raise the average height of your citizens by one inch! In passing I can not help expressing my pity for any official in charge of a department of state dealing with any such duties! But what I really wish you here to note is that mental qualities though not as easily measured as physical characteristics, are distributed in accordance with the same laws and are no more easily improved by dealing with selected groups. Does not this way of regarding the matter throw serious doubts on the ultimate advantages of eugenic reform of this kind; that is, of picking out a comparatively small number of selected persons on account of qualities dependent on many factors. Our main endeavor ought to be to raise the level of the whole people in regard to their inborn qualities, for which purpose large numbers must be affected; and I am inclined to believe that the success of our efforts to promote racial progress will depend largely on this fact being fully recognized by eugenic reformers.

Since we are getting on well enough as we are, why not let things alone? Before adopting the hopeful attitude indicated by this inquiry we ought carefully to consider whether at the present time civilized nations are advancing or deteriorating in regard to their inborn qualities; a most difficult question to answer decisively. Here we enter the region where keen feelings are likely to be aroused; and, to avoid the distorting effect of prejudice, let us look to the future rather than to the present. Now these young men of to-day who are endowed with good natural abilities and constitutions will be nearly all certain in time to earn for themselves a fairly good livelihood, whilst the reverse will be the case with those ill-endowed by nature. Then again, those

[3] The increase in stature would in truth be materially less than .002 of an inch; for regression due to dominance and other circumstances has to be taken into account. See "Correlation between Relatives," R. A. Fisher *Trans. Royal Soc. Edin.* Vol. III, Part 2 (No. 15).

who are members of small families will receive greater advantages in education and in many other respects than will the members of big families and they will in consequence more easily win their way to the front. These two selective processes will be more effective as civilization advances; and as a result we may expect to find in the future in the ranks of the well to do a most harmful combination of qualities more and more often appearing; that is to say, superior inborn qualities more and more often combined with all those natural tendencies which tend to favor the production of small families; these latter including natural infertility and an innate desire to consider the welfare of children as yet unborn. The result to be anticipated is that, in comparison with the ill-endowed, the naturally well-endowed will as time goes on take a smaller and smaller part in the production of the coming generations, with a tendency to progressive racial deterioration as an inevitable consequence.[4] And if we ask whether existent facts confirm or refute this dismal forecast, what do we find? Statistical inquiries at all events prove conclusively that, where good incomes are being won, there the families are on the average very small. Moreover, history teaches us that in the remote past ancient civilizations, after rising to a climax, often began to sink and sink until they disappeared off the face of the earth. These problems are too complex now to be discussed at length; and I can only assert that I can find no facts which refute the theoretical conclusion that the inborn qualities of civilized communities are deteriorating, a process which must inevitably lead in time to an all round downward movement. I am, of course, regarding this question broadly and generally, but I can not refrain from adding that the United States has a mighty future before it, on which the civilization of the whole world may in a large measure depend. It is, therefore, doubly incumbent on its citizens to consider whether their best or their worst stocks are now multiplying most rapidly. If it is the worst stocks, and if no steps are taken to remedy the evil, then this country may in consequence miss an opportunity of filling a most glorious page in future history.

[4] The theoretical side of all these questions is here quite inadequately discussed. Many authorities have pointed out the effect of wealth in reducing fertility, a subject not here dealt with, though I have been convinced it is a most important factor. As to the possible influence of physiological infertility, see "Human Fertility" by J. A. Cobb, *Eugenics Review,* January 1913. As to the effect of mental traits on fertility and racial progress, see "Some Hopes of a Eugenist" by R. A. Fisher, *Eugenics Review,* January 1914. These topics have been discussed by me at greater length in "The Need for Widespread Eugenic Reform," *Eugenics Review,* October 1918; "Eugenics in Relation to Economics and Statistics," *Journal of Royal Statistical Society,* January 1919; "Some Birth Rate Problems," *Eugenics Review,* October 1920 and January 1921. See also "The Habitual Criminal," *Eugenics Review,* October 1914.

If in all civilized countries the forces the existence of which I have but too briefly indicated, are producing deteriorating influences by acting on the masses of the people, then the only way to counteract this tendency is to set in operation other forces which will affect large numbers in the opposite direction. But how is this to be accomplished? As to good qualities, what I hold to be the main remedy can be expressed in so few words that its great importance is likely to be overlooked. What is necessary is to make it widely and deeply felt that it is both immoral and unpatriotic for couples sound in mind and body to unduly limit the size of their families. No doubt difficulties will be experienced in deciding to what extent the duty of parenthood is imposed in individual cases; difficulties which I have no time to discuss. The main difficulty will, however, be to get this duty strongly felt by the mass of the people; for success in this endeavor would, I am convinced, have a much greater effect on the size of families than common sense alone would indicate. Failure is, however, certain if the problem is not attacked with religious zeal. There ought to be a great moral campaign against the selfish regard for personal comfort and social advancement, for these aims must in a measure be sacrificed on the altar of family life if racial progress is to be insured. We must all learn that if envy and jealousy could be banished, the happiness of our children would depend greatly on their inborn qualities and but little on their place in society. We should recognize that we shall best serve our country by bringing healthy and intelligent children into the world, provided that we can give them a sound education and a fair chance of winning a good livelihood; and all of us should be ready to make some sacrifice of social position in order to obey our country's call in this respect. The nation that wins in this moral campaign will have gone half way towards gaining an all round racial victory.

There are no doubt many economic methods of increasing the rate of multiplication of the people; methods which would be beneficial if applied to good stocks and harmful in the case of inferior types. The main reason why persons of high character limit the size of their families is in order to insure that all the children they do bring into the world shall have a good start in life. Obviously the simplest way to remove this check on fertility is for the state to step in and ease the financial strain on parents due to the upbringing of their children. This method must, however, never be applied indiscriminately or without consideration, for the qualities of the types affected must ever be held in view; and this is especially to be noted in connection with all schemes for motherhood endowment. Then again an increase of taxation is equivalent to an increase in the poverty or a decrease in the wealth of the persons taxed; and such a change in their prospects will tend to make all couples still further limit the size of their families;

unless indeed they are naturally incapable of taking thought for the morrow.[5] It follows that to increase the taxation on the more fit in order to ease the strain of family life amongst the less fit would do a double dose of harm; that is by decreasing the output of children where it should be increased and by increasing it where it should be diminished. There are no doubt evils which can not altogether be avoided; for we are bound to pay attention to the needs of all who suffer, whatever may be their natural qualities. If only looking to the types whose multiplication we want to promote, what we can safely do is to increase the taxation on the unmarried and the childless and, out of the proceeds, to give advantages to the parent of growing families *in the same social stratum*. In regard to all proposals such as that recently made in Australia, for directly or indirectly taking from all workmen a portion of their earnings and for distributing the money thus obtained amongst parents in proportion to the number of their young children, here again the racial effects will be good if, and only if, the benefits received by each couple are porportionate to the contributions made by members of the same group to which they belong, a condition almost certain to be neglected. The economic principles, which I have all too hastily alluded to, involve many puzzling questions in regard to their application; but to neglect them altogether is to court a great racial danger.

Turning to the consideration of influences which would tend to diminish the rate of multiplication of inferior types, we see that the grossly unfit can be separated from the normal population with but little doubt, and that they are often a serious nuisance to society. As regards most of these types it is probable that seven mendelian factors are involved; but even if that be so it is not improbable that some one of the resulting bad qualities may be due to a single factor. For all these reasons it seems right that the grossly unfit should be selected individually from the rest of the population, and that in their case parenthood should be prevented by segregation, with voluntary sterilization as an experimental auxiliary. But here also some attention should be paid to the principle which I am advocating, namely, that with qualities dependent on many factors it is as a rule best to aim at dealing with large numbers rather than with the extreme cases. Taking the criminal population as a single example, it is found that those who have been frequently in prison are practically certain to revert to crime when liberated. These habitual criminals form the bulk of the prison population; they have no good qualities to recommend them; they are too stupid to avoid detection, and the only courage

[5] It should be noted that I am speaking of an *increase* of taxation and not of high taxation. The ultimate racial effects of high taxation are difficult to foretell.

which they show is that needed to face disgrace and imprisonment. Merely to reduce the fertility of large numbers of this class would be more beneficial from the racial point of view than to absolutely prohibit parenthood in the case of a small number of persons convicted of grave crimes; persons who at all events are often intelligent and courageous. With the habitual criminal the length of detention should be increased and its severity diminished after each conviction; periods of liberty should be given until it is quite certain that no cure can be effected; and in the end the malefactor should be regarded as a person to be permanently detained because he is incapable of self management, all idea of punishment being abandoned. The benefits thus to be derived are indicated by the statistically proved facts that lengthy imprisonment does lessen the number of progeny of the criminal, and that his children are at least ten times more likely to be sent to prison than are the children of honest parents. Even those who do not believe in heredity may, therefore, be inclined to hold that permanent segregation is justifiable after many convictions. We should endeavor to deal in the same way with the wastrel, the drunkard, and the work shy; that is as members of large classes the size of which ought to be diminished rather than as individuals requiring separate consideration.

If it be true, as I hold, that there are hidden forces continually at work tending to relatively increase the rate of multiplication of large numbers of those who are below the average in the various qualities held to be desirable, then efforts to deal with the obviously unfit would not alone stem this tendency toward racial deterioration. To prevent our civilization from slowly sinking in the future, some far more widespread action is needed. But how are we, it may be well to ask, to pick out large numbers of the population whose hereditary influence on posterity will tend to drag down the average? [6] Now we shall all probably agree that the fewer young men there are in any country, who prove themselves to be incapable of winning sufficient wages to maintain a family in decency, the better it will be for the community as a whole. This is true even if we only look to the comfort and well being of the children destined to be born in these ill-found homes. Here we are of course tempted to urge that the state should step in and see to it that no disadvantages are felt by the little unfortunates likely to be brought up in bad surroundings for which they would be in no way responsible. Any such action would, however, increase the birth rate of the class affected. Now bad surroundings doubtless tend to increase the number of social failures; a cause of failure which, we may believe will become less and less operative with every advance in civilization. But a very large proportion of those incapable of support-

[6] It must be remembered that this must be true of half the population.

ing a family in decency in normally prosperous times are characterized by certain inborn defects; such as weak constitutions, inferior mental powers, unstable moral qualities, etc., all of which are in a measure to be passed on to posterity. State action of the kind just suggested must therefore be harmful in its racial effects; for we ought to check rather than to increase the size of families born in squalid surroundings. How can this be done? This is a problem to which I most earnestly hope that eugenists will turn their attention; for I confess I have found myself no very satisfactory solution. I can only suggest that state and charitable aid should never be given in such profusion as to prevent the appearance of each child from causing any additional financial strain on the household, for fertility is decreased by financial pressure; but I hardly know what to suggest in the case of those who in spite of this pressure persist in procreation in evil surroundings; and perhaps for the present we should concentrate our attention on the attempt to secure a general approval of the desire to lessen the output of children in such circumstances. But the problems involved must be solved sooner or later, and in attempting to solve them we must remember that every reform does harm as well as good, and that all we can do is to make reasonably certain that the good results will preponderate over the evil. In order to prevent the civilized nations of the world from slowly losing what has been won by long ages of suffering, no doubt sacrifices must be made and some suffering yet endured. But if we have courage to face this problem without flinching; if we fearlessly advocate what we hold to be right, in spite of the unpopularity of the safeguards and remedies we suggest; and if we can in the end secure wide approval of our aims; then I am myself certain that we shall be able to introduce reforms which will secure untold benefits for mankind, in all the long, long ages to come.

In conclusion may I once again indicate the contrast which, I suggest, ought always to be held in view in framing plans for eugenic reform; a contrast which I have painted with such a broad brush that many qualifications have of necessity been omitted and many points but ill-explained. I have endeavored to show that, for the purpose of our discussions, human qualities may be divided into two ill-defined groups, with intermediate types between them. At the one extreme there are the single factor qualities; in the case of persons possessing bad qualities near this end of the series, they should be individually selected and examined and then each treated accordingly. Here we should be dealing for the most part with pathological cases or with persons who are likely to become a nuisance to society; the aim of the eugenic reformer would usually be to rid the world of some definite defect. These are the cases which are least in dispute, and where racial benefits can be most rapidly obtained; and for these reasons it is perhaps

to these qualities that our attention should first of all be directed. At the other extreme are those characteristics which separate whole classes of a community from each other, and which obviously depend on a great many factors. Here we generally have to look to the class as a whole, and to apply such remedies as do not necessitate the selection of individuals, the aim being to raise the level of the whole people. It is on such qualities as these that the slow improvement or deterioration of our civilization will in the main ultimately depend; and if they be neglected in our schemes of eugenic reform, we shall before very long begin to lapse back again towards barbarism, thus following in the footsteps of many highly cultivated nations in the past. On the other hand, if our biologists face these problems more earnestly in the future than they have in the past, if our politicians pay more attention to the advice of scientific experts than has hitherto been customary, and if the general public will be guided by common sense in regard to heredity, then I hold that we shall have more right to look with confidence to the future than ever has been the case since the dawn of civilization.

THE CONSEQUENCES OF WAR AND THE BIRTH RATE IN FRANCE

By M. LUCIEN MARCH

TREASURER OF LA SOCIÉTÉ FRANCAISE D'EUGENIQUE

AS a result of the war, the France of 1914 has lost 1,400,000 of her inhabitants in the prime of life, most of them fit for producing children. And among the survivors of the fighters of the great war, a certain part of the 800,000 total invalids will never be able to produce strong healthy children, either because they are no longer capable of marrying, or because they are affected with tuberculosis or other constitutional maladies.

To these direct losses must be added the loss of births. Before the war, the number of living births balanced with a slight excess the number of deaths; the annual number was about 750,000. During the six years from 1914 to 1919 inclusive, the deficit reached 400,000 births, which ought to have survived normally and which were lost owing to the war.

On the other hand, deaths in the civil population have been more numerous than formerly, so that 400,000 more deaths are added to the 1,400,000 unborn and to the 1,400,000 soldiers killed in war, giving a total of more than 2,000,000, taking into consideration possible repetition and immigration. These results are calculated on the supposition that, in the invaded regions, the loss, estimated proportionally to the number of inhabitants, was the same as in the uninvaded territory; on the other hand, the numbers are applied to the territory of 1914, but Alsace and Lorraine can not nearly fill the loss of population of this region. The provisional results of the census of 1921 confirm these suppositions.

But that is not all. Privations have broken down the health of many children born during the war or a few years before, especially in the regions of the northeast, where, during the German occupation, they lived in a state of veritable physical misery. Indeed, infant mortality, even in the uninvaded districts, has been notably higher during the war than before, in spite of the low birth rate.

Finally, a certain recrudescence of alcoholism, tuberculosis, venereal disease and various nervous diseases influenced unfavorably the vitality of the nation and the race.

Many years will be necessary to repair the loss of population, direct

or indirect, attributable to the war or to the evils which have accompanied it.

To avoid the inauspicious consequences of these miseries, certain people believe it is necessary to encourage procreation by all possible means; they do not fear an excess of population for a long time. Others think it expedient that each man of proper age to have offspring should have the 3 or 4 children necessary to permit a moderate increase of population. And still others estimate that a continued increase of population would create an economic peril and contain the germ of future wars. Again some wish certain restrictions, especially in confinements, among the poorest of the population, to improve the quality of this population.

The considerations which are the most important are the following, which shall be examined from the point of view of eugenics and the point of view of economics.

I.

To-day, respect of human life in all its degrees makes us condemn infanticide and abortion. There remains then as a means of artificial selection only the prevention of births.

But the universal concern which determines parents to limit the number of their children is the burden, at least momentarily, which the latter represent.

The question of the birth rate, in its entirety, with an exception to be referred to later, comes back again to a question of economic morale. For physical passion finds play without producing the being which is its end, and this being is often to-day the reward of a sacrifice freely agreed upon.

Humanity ought not to perish by its own error. Such is the higher principle which ought to be reconciled with the practical impossibility of unlimited multiplication.

According to etymology and the definition given by Galton, eugenics is a general study of the improvements of which the race is susceptible, race being characterized by common physical or mental qualities manifesting themselves in certain groups of men and differentiating them from other groups. Two conceptions enter here, that of improvement, and that of the race. To what realities do they correspond?

We cannot define progress, the process of making perfect; but, when we look back, we feel the differences which separate the life of other times from that of the present; evolution appears to us to follow a certain direction. We can then legitimately aim to continue life in this direction.

In the second place, although in a biological sense pure human races are not numerous, one can prove that a number of groups of in-

dividuals are distinguished by their physical and mental characters, apparent and distinct as a whole, from another group. Without modifying these characters to the point of making the differences disappear, one can improve their manifestations, the manner in which they act in each human group; that is the aim which eugenics seeks. But we must not lose sight of the fact—for other sciences, the science of education for example, seek the same end—that eugenics is concerned, it seems, only with measures capable of effect upon descendants, that is to say, transmissible by heredity or capable of operating a selection advantageous for future generations.

The general principles of this new science have not yet been well established. It is not yet settled; it is still in a period of development. And this permits some liberty, some difference of opinion to those who try to attack the problem.

There are, however, acquired facts, indisputable connections; for the moment we may withdraw to this ground.

Whatever our opinion as to the relative importance of the factors heredity or environment—that is the principal point on which personal opinions are opposed—the influence of heredity can not be denied. Physical and mental resemblances of parents and children are obvious; the hereditary transmission, at least in the most closely related generations, of certain physical peculiarities, such as stature, conformation of the skull, hemophilia, polydactylism, etc., or of mental defects such as epilepsy, certain forms of mental deficiency or feeblemindedness, are to-day almost proved. Provided always that the tendencies involved are simple and that their existence can be removed, resemblances between children born of the same parents do not prevent great differences sometimes appearing in these children. The heredity of abilities or that of defects is not a matter of fate: education may modify nature.

As to the influence of environment, of the mode of development of the created being, whatever may be its importance for this being itself, the question which interests eugenics is to know whether this influence acts upon the descendants after being hidden for a number of generations. On this point, certain savants, Weismann in particular, have declared negatively. Others have shown, by experiments on lower organisms, that organic modifications brought about in these organisms are transmitted to their descendants.

As Dr. Apert has remarked in France, as far as man is concerned, it seems that only the modifications relating to the nervous system have yielded, up to the present, observations truly conclusive. Yet the interpretation of these facts has been contested; they have been attributed to hereditary predispositions, but it is always easy to draw into the re-

sults of an observation the effect of a hidden influence as mysterious as that of heredity.

Our knowledge is not sufficient to warrant our issuing a challenge on these obscure questions. And yet of such great importance to humanity is a sustained and growing development of scientific researches relative to the heredity of man, that this is the desire of all those who are interested in eugenics.

The transmission of character, from one generation to another, works through the germ-plasm, but this action can be guided by selection: natural selection by death, artificial selection by sexual union.

M. Edmond Perrier, president of the Société française d' Eugénique, recently stated that, in primitive nature, natural selection may not have had the exclusive effect which the Darwinians have attributed to it. Moreover, what precisely is natural selection? Does it mean simply that an individual incapable of adapting itself to the conditions imposed on it by environment disappears and only those individuals survive who are capable of adapting themselves? That does not add a great deal to our knowledge, as Mr. Balfour (speaking before the First International Eugenics Congress) remarked, since it amounts to saying that only those are capable of surviving who survive a veritable truism. And if one means that only those survive who are capable of surviving, M. Perrier answers (*Eugénique*, mai 1921, page 197) that those who are incapable of surviving in one region can escape death by flight, and it is thus perhaps that the living world has evolved.

In truth, death and survival are a form of selection from which may result for humanity, as for all living beings, good or evil according to the qualities of the individual involved and the surrounding circumstances. If we are unable to modify the innate qualities of the individual, we may often, by acting upon the surrounding circumstances, make useful the qualities which it has.

This is one of the essential duties of eugenics: to favor and encourage the work of health and the work of educating the promoters of social progress.

As to artificial selection, we may endeavor to increase births among those who possess the best qualities and to decrease births among those who show defects and faults. However, we ought to ask ourselves whether there does not exist now and then a certain opposition to these two movements: that which makes for the improvement of conditions of existence and that which makes for the best qualities in the descendants.

Opposition has been noted many times, especially among English eugenicists. Nature, they say, in a convenient anthropomorphic language, nature has arranged for the beings least endowed for life, to disappear before those who are better endowed. This observation

is just; admitting that in the shadowy beginning of life, flight was a means of preservation, this means is not worth much when it is impossible to flee from danger. This is the case when illnesses and bodily struggles cause the disappearance of the least worthy beings, the least capable of resistance. But when human fraternity, pity, science, and hygiene unite their efforts to defend the weak, many individuals who would have disappeared if left to themselves, live in spite of their disabilities and transmit these to their descendants. As is often remarked, the humanitarian tendencies of our time, our social legislation and all the measures which come from the same principle, have this effect—of which people are not sufficiently warned—to oppose the play of natural selection. This manner of thinking contains a great deal of truth. However, no defender of eugenics thinks of suppressing pity, or hygiene, to reestablish natural selection in its barbaric despotism. The efforts of humanity tend to utilize the natural forces for their own ends and not to let them act blindly. Also when the ideal of healthfulness and social progress is opposed to the ideal of perfection of race, because the first is contrary to the effect of natural selection, it becomes necessary to demand from artificial selection much more important effects, and especially those better regulated, than those which it produces among primitive peoples.

This we shall now consider in passing to the special question of birth. Even though we can lessen the effects of natural selection, we can much more surely intervene by artificial selection to favor the perfecting of the race and above all to prevent its degeneration. The point is to make good use of this power.

II.

In all times, man has tried to deal with the multiplication of his race. Independently of wars, famines, epidemics, whose destructive effects extend themselves over entire populations, suppression of infants already born, abortion, and prevention of births have been practised.

Eugenics, as well as economics, can, to be sure, tell us what the social interest demands. From the point of view of eugenics, the experience of centuries and of numerous researches teaches us above all that there are transmissible defects, reproduction of which must be avoided at all costs. These are notably the hereditary predispositions to insanity, to feeble-mindedness, to epilepsy, and to detrimental malformations; or again the acquired dispositions chargeable to the poisons of the nervous system, such as alcohol and the spirochete of syphilis.

Evidently one can not always be sure in advance of the effect of those influences which, acting in the mass, result in differences. Never-

theless there are individuals whose duty it is not to procreate, not to give birth to offspring, since the chances of deformity or mental deficiency are really too great. This duty is all the clearer when one is forced to conserve the life of those beings who, in other times, would have been condemned to a more rapid death by the brutalities of existence.

Apart from circumstances which justify and command abstinence, there are still others which can be drawn in very legitimately to limit the number of children; for instance, in the very crowded urban districts, the insufficiency of homes and the promiscuity cause an excessive mortality when families are large, and there are no means for choosing spacious dwellings. Finally, there are individual proprieties worthy of respect, for example, the care of the mother's health when she cannot stand numerous pregnancies, not to speak of the limits which can impose the legitimate fear of an undeserved loss, if a large family assumes a burden which surpasses its strength.

We cannot then accept the formula of an unfortunate equality, which would impose on all adults the obligation of having a determined number of children, any more than we would dream of recommending an unlimited fecundity. It is therefore necessary to discard formulas which are precise but too simple and to keep within the bounds of asking that each adult have children if he reasonably can. Each one, in fact, has the duty of transmitting the life that he has received, as well as of improving the value of that life just as those who have preceded have striven to do. And thus is imposed, according to the limits of one's means and capacities, the duty of perpetuating the family to which one belongs, the duty of contributing to the scope of one's country and to the progress of all humanity.

The formula is doubtless very vague; it is addressed to conscience, for it is conscience alone which is the judge of the degree to which the order has been obeyed. It is the same as when one appeals to the conscience of each one to participate in the defence of country or of national burdens. In this case, it is true that legislation enforces the moral obligation; is it not necessary that legislation also intervene in favor of the birth rate? The answer to this question is not doubtful; we can not omit a certain social organization capable of stimulating conscience and assuring the desired result, that is to say, the number of births which appear necessary for the whole population.

However, two objections have been made. One declares that before increasing the birth rate, it would be better to reduce mortality and, above all, infant mortality.

It is obvious that all measures capable of reducing mortality are good in themselves. But, since the remotest historical times, it has not appeared possible to lengthen the maximum of human life. We can

only hope to lengthen the mean duration of life. But that will not produce an appreciable increase in population in the countries where the number of births depends on familial foresight, when the parents determine, so to speak, in advance the number of children they will raise. Three years out of four in France, the number of births in one year is related to the number of infants who have died in the preceding; if many children die, they are replaced.

The second objection is that instead of seeking the striving for a great number of children, it is preferable to concern oneself about the quality. We have seen that the quality of population is in fact the principal aim of eugenics.

We shall consider successively the family and the nation.

In the family, when the number of children does not exceed the reasonable limit of which we have spoken, one can affirm that quality, far from being opposed to quantity, goes hand in hand with it. The case of the only child has often been tried. Numerous examples have also been cited of brilliant men who are among the young members of families, sometimes of very high rank.

As to the nation, she may claim a certain choice, a selection the importance of which we have mentioned in the first part of this paper.

But, admitting that those who carry defects are to be prevented from procreating, what sign enables us to recognize inferiority and superiority of qualities? It has been proposed to take wealth for an index. Numerous inquiries have proved in fact that in the slums of cities, among the individuals who have no care for the morrow, are found the greatest number of transmissible defects and the most afflicted children. On the other hand, manifestations of intelligence and various abilities have appeared more frequently in the children of well-to-do families than among those of poor families.

But here the influence of environment as well as that of education is considerable. Omitting the small part of the population which is composed principally of social outcasts, we can not but affirm that the innate qualities (we do not speak of acquired qualities) are less in the families of small income than those of large income, especially if one takes into consideration all classes of population, city and country, intellectual and artisan.

Reserving the elimination of undesirables, it does not seem that there is serious reason, from the single point of view of eugenics, to seek births in one class of population more than in another. The numerous statements which have been made on the retrogression or even the degeneration of families which have not renewed themselves sufficiently, tend on the contrary to promote the incessant mixing of social classes rather than their separation. When one considers the state of the population, one perceives great differences in the birth rate.

In France, the birth rate is generally greater in the country than in the city, greater in the mountainous regions than in the valleys, greater among agriculturists, sailors, fishermen, the colliers of the north, the heads of great industries, than in the middle classes, among artisans and especially among clerks. These differences explain themselves; they appear in the nature of things, and, for the moment at least, they do not carry any danger. We know that depopulation does not reach the towns, which are being filled unceasingly by an influx of inhabitants from the country. It is then the birth rate in the country upon which effort should principally be brought to bear; it is there that results can be gained most easily, at the least expense and under the best conditions from the point of view of hygiene, as well as from the point of view of eugenics.

Moreover, social action ought not to confine itself to facilitating the birth of children; it is also necessary to raise children up to a certain age. Questions of education, emigration and immigration are also questions on which eugenics has something to say, especially the question of immigration which has gained since the war an importance and character previously unknown in France.

Eugenics has also something to say on the psychological and moral side of the question of birth rate. Prevention of births, regarded as necessary in a certain measure, can be recommended only according to the means indicated by Malthus; the delay of marriage.

Fecundity of marriage, which one supposes sufficient to allow the maintenance of a healthy family well adapted to life, ought not to be fettered by an excessive fear of life, or by the fear of effort. No hope of the future can be realized except with a certain present sacrifice. It is necessary to make some personal sacrifices and to have hope in the future.

These sacrifices will be moreover fruitful for posterity. In what measure can they be shared; what profit can they yield for it? That is what the examination of the question from the point of view of economics will show.

III.

The economic power of a country depends primarily on its producers, that is to say, on those who by their work render natural riches serviceable.

Now we have already seen the loss of population since the war. The loss comes principally from the avoidance of marriage. During the war, many young men rightly wished to wait for the end of hostilities before marrying. Hence has resulted the increase of marriages in 1919 and 1920. The same phenomenon has been observed after all wars; it is easily explained.

But in spite of this the deficit is an important fact in our country and in Belgium. While the population of Great Britain has increased by 1,300,000 during the same time, that of Germany has hardly diminished and if it has diminished at all, we are still ignorant of it.

Imagine the state of the French population in fifteen years. At that time, there will be lacking, taking account of the mortality, 500,000 young men of the ages of 15 to 21 years, a loss which must be added to the 1,400,000 men of 18 to 50 years of age killed during the war, and who would then be 33 to 65 years old, as well as the 500,000 young men of the same ages who have died in the civil population in excess of the normal mortality. In all, about 2,000,000 individuals will be missing from the male population of 15 to 65 years.

In 1935 one sixth of those whose work must furnish the principal source of income of the nation will be lacking. In spite of the restoration of Alsace-Lorraine, which brings us 400,000 adults of 15 to 65 years but which also demands workers for its fields and iron foundries, it is certain that French production will be deprived of an important part of its active forces and that the economic life of the country will languish for many years if energetic measures are not taken without delay to ward off the threatening deficit.

Without doubt, one might temporarily appeal to foreign workers. Assimilable populations, however, can furnish only a small part. It will be necessary to have recourse to unassimilable races very different from ours, which will quickly furnish undesirable elements.

The deficit of male workers has caused the more general employment of women. But the women who work cannot be fruitful mothers. Feminine work will be only a short-lived mitigation.

For all time, since the infant brings care and pain as well as joy, maternity has been a cause of care and effort. Among primitive tribes which are displaced, it is necessary not only to nourish but even to carry these children. In our civilized societies, and especially in urban centers, where civilization is most refined, the burden is often very heavy. The difficulties of lodging, the hindrances of traffic, the care for appearance, which is applicable to children as well as to parents, the care for the health of the mother and all the complications of urban life; the laws for working women, the educational obligations and the impossibility, in poor families, of using the work of young children, make the maintenance of even a limited number of children sufficiently burdensome.

Formerly in poor families, who are the most numerous, the help which grown children gave to their old parents, compensated in some measure for the privations which they had caused at first. To-day, collective insurance is substituted for this kind of family insurance of previous times. In consequence, the child usually never brings any

repayment in exchange for what he cost. Also the care for his future causes the foresighted parents of our time to assure themselves of the excellent probabilities of his future establishment, which leads them also to restrain their responsibility. When the children may soon be an aid to the family, the burden is much lighter. Moreover one finds the greatest number of children among the people chiefly concerned with agriculture, and, in every country, in the rural populations.

However, the first obstacle to births is the possibility of raising the children. Doubtless this obstacle exists for many animal species and does not hinder their fecundity, but in those species there is no reasoning power, no foresight, no respect of life, at least in a degree comparable to that which may be observed in civilized human society.

A second obstacle, which does not exist in any degree outside of humanity, is the foresight of parents exercised beyond the time of growth of their children. It is not sufficient to have brought children into the world and to have raised them to an age when they have strength enough to answer for themselves; the environment in which they are placed must permit them to live. To understand the economic mechanism of the phenomenon of birth it is convenient to distinguish three orders of circumstances:

1. The means of keeping children alive during their growth.
2. The eventual means by which these children can live by themselves after growth.
3. The view of parents on these future circumstances.

It is necessary to understand here by means of life, the means of leading a certain kind of life; one can say in general that it is a kind of life at least equal to that to which the parents are accustomed. Often even, the parents desire their children to reach a higher stage of life.

But the means of living are governed in part by circumstances external to living beings and in part by the circumstances which depend on these beings themselves. The analysis of these circumstances makes up what is called the theory of population.

Long before Malthus, who formulated this theory, estimates had been made of the facility of increasing the human species, a faculty analogous to that of every other living species, when no limitation intervenes. It is wrong to censure Malthus for having employed the formula of geometric progression, since a simple reasoning founded on a not dissimilar hypothesis establishes it. Where Malthus appears to be mistaken is in his attempt to justify his law by experience or to deduce from one isolated experience the reason of progression. If he could have extended his observations still farther, he would have seen that this reason was not constant, and in consequence the progression was not geometric.

If on the contrary one keeps to the domain of hypothesis, as others

had done before Malthus, then supposing that nothing limits the fecundity of women, as a woman can bring into the world at least 8 children, and taking account of cases of involuntary sterility and physiological mortality, it is easy to understand that in thirty years a population not meeting any obstacle would increase in the proportion of 1 to 4 at least, that is to say, that it would be more than doubled in 15 years.

Malthus admitted that the population of the United States doubled every 25 years; a more rapid progression has been cited, that of the Hebrews passing through Egypt: 70 adults became 600,000 in two centuries, which means a doubling in exactly every fifteen years, and corresponds to the period of doubling of capital placed at interest of 5 per cent. a year. Every one knows what a fantastic sum is reached with a sufficient number of periods of doubling. If the doubling every 15 years had taken place since the beginning of historic times, the men living in our time not only could not find place on earth, but would even fill the space which separates our globe from far distant stars. The hypothesis which leads to an idea of constant geometric progression is not verified by facts. In reality the matter changes with the times because of obstacles which meet the indefinite multiplication of a species, for men as well as for all living beings. The interest of the work of Malthus is that this author has classified the obstacles and made a choice.

A second error, which is often made, consists in assigning also a general law to the development of the means of existence. These can only increase by following an arithmetic progression.

This supposed law has no theoretic foundation, even admitting that one works in a limited territory, since the production of subsistence depends on putting to work the means of production. In fact the means of existence have progressed much more rapidly in certain epochs than in others. In the nineteenth century for example, the population of the most civilized states increased more rapidly than during the previous centuries. There is then no general law for increase of population.

If one applies the formula which would recapitulate the theoretic movement of population, one would begin to say that population is developed in the measure that the means of living are developed, that there is a correlation between the two phenomena. But this vague formula is only pure tautology, since one can not conceive of a population which would develop without means of life. Such a formula can serve only as a preliminary to a true theory of population. In order to have a theory, one must indicate some mechanism for the relation between population and the means of subsistence.

The theory of Malthus tends to establish the fact that individuals,

according to nature, have an action weaker than the reaction exercised by it. Inversely, other theorists, before Malthus the mercantilists and populationists, after Malthus the advocates of patriotic fecundity, have claimed that, in certain limits at least, man could always obtain from nature what he needed to live. These two theories have been translated by picturesque formulas.

Where bread is born, man is born, say those who believe in blind fecundity and limited productivity. Where man is born, bread is born, answer those who measure the limitation of fecundity and have faith in the powers of invention.

In reality these brief formulas are too general: in some epochs, and countries natural increase of population tends to diminish production; in other cases the contrary is true.

In China, in India, when the population is increased to a certain degree, a deficient production results in veritable hecatombs of human beings, after which equilibrium is restored. In other countries where patriarchal life has given place to a complicated organization founded on the division of labor and the specialization of services, the means of production increase sometimes to such a point that production surpasses the needs. In this case, it is true, the conditions of existence of the people are in a mutual dependence, and this dependence gives rise to terrible conflicts.

In the human species, as in all living beings, death appears as an inflexible regulator of the interaction of the two factors of life: natural fecundity and nourishment. But, in the human species, the individuals are capable of foreseeing in some measure future events; foresight is the principal instrument of progress of the species and of civilization. Malthus has well noted this difference between the human species and others, and he has declared that for the brutal regulator of other species one may substitute that of reason. This has been expressed, in rather rude form, by a German economist, Julius Wolf, who sees in the universal decrease of the birth rate the effect of rationalism increasing life.

However, Malthus has not seen the importance which this factor will have and the danger which will result when this factor is capable of suppressing all the principles of life. He believed, on the contrary, that the power of instinct would always be stronger than the fear of overpopulation, and he impregnated the thought of his century with a dangerous pessimism.

But is it true that increase of population is necessarily a menace to the existence of this population? The facts answer for themselves. Not only has the 19th century seen the civilized nations increase in proportions unknown in the preceding centuries without these nations having suffered want; but, among them, the most rapid increase in wealth

has gone with the most rapid increase in population. In England at the beginning of the 19th century, poor laws imposed excessive burdens on the parishes, misery ruled and the lamentable state of the population at the beginning of the age of machinery justified later, in the eyes of Karl Marx, its attacks against the capitalistic régime. Since then the production of foodstuffs has diminished, and the population has quadrupled from 9 to 36 million (1911).

At the beginning of the nineteenth century an increase of population was feared in Germany as much as in England. Measures for restraining marriages were even passed in the legislatures of certain states such as Bavaria and Würtemberg. In order to have the right to marry, one had to show sufficient means. Thanks to these restrictive measures and to propaganda, the increase of population remained very slow—slower than in France—during a great part of the nineteenth century. Thus during the period of 25 years, 1847-1871, the number of inhabitants increased 13 per cent. in Bavaria, and 9 per cent. in Würtemberg, while they increased 17 per cent. in France.

Events happened which transformed the state of mind, and without doubt the faith in the future, without modifying the natural conditions of production, and the view changes. During a second period of 35 years, from 1871 to 1915, the number of inhabitants increased 34 per cent. in Bavaria and 27 per cent. in Würtemberg, while the proportional increase fell to 9 per cent. in France.

A good element of appreciation of the activity and the power of expansion of a people is furnished by the development of its exports, or, if we consider ten states for which we can give at the same time the proportional increase of the number of inhabitants from 1875 to 1913 and the relative progress of exports, a close relation between the two movements is proved.

PROPORTIONAL INCREASE BETWEEN 1875 AND 1913

	Population Per cent.	Exports Per cent.
France	10	80
Italy	29	145
United Kingdom	45	160
Belgium	54	237
Russia	65	260
Austria-Hungary	38	383
German Empire	58	380
Canada	103	423
United States	138	386
Argentine Republic	330	828

The two series of numbers vary in the same direction.

IV.

What is to be concluded from these results? Simply that the phenomenon is too complex to be analyzed in its entirety without going back to elemental facts.

Let us turn to the father of the family, for it is in fact upon the fathers of families that the birth rate of the country depends. We have said that this decision depended most generally on three factors:

1. The expense represented by bringing up a child to the time when it can care for itself.

2. The chances this child has of living effectively, at least in the conditions under which its parents have lived.

3. The view of the parents on this expense and these chances.

Other factors intervene also: considerations of health, well-being, etc., but we will concern ourselves only with those which are most general and least synthetic.

It is not regrettable that, in this grave question, reason is substituted for the most simple instincts. We must force ourselves to see only that which commands the true meaning of things.

At the origin of the problem of the birth rate are found two economic and one psychological fact. This last dominates the two others, particularly the second. Moreover the psychological fact intervenes only where the customs and legislation are directed by the sentiment of respect for life. For among the primitive peoples, abortion and infanticide excuse the parents from thinking of the future. They let the sexual instinct act freely, for they may cause to disappear the results of this action, sometimes, as in Sparta, with the illusory forethought of selecting the survivors.

In our modern society, these procedures are no longer permitted; they are supplanted by the prevention of births; that is left to the will of the parents who bear the burdens. But this will is guided by judgment and sentiment. If judgment is clear and sound, if sentiment is right, the voluntary action will be well directed; in the contrary case, it will come to evil. But the first condition, in order that the parents be not hindered by a too fearful foresight, that they may act in a sense best conforming to the good of society of which they are a part, is that they have a certain moral force, that they know how to sacrifice a little of their personal interest to the common interest—for maternity always brings some sacrifice, at least physical—and that they have confidence in the future. One may say that the question of population is above all a moral question. A certain optimism is necessary but this optimism ought to follow from facts.

It is always imprudent to ask too much of the sentiment of duty when one addresses a whole population. During the war, when invasion roused patriotism, it was necessary to impose military service by force.

Even when it is a question of the birth rate, when general education, when the comparison of military or economic power of the country shows all families a common duty, nothing better is needed.

However, although in this matter no sanction will be legitimate or efficacious, still it will be proper to facilitate the accomplishment of this duty.

What concerns provision for the future is one of the legitimate preoccupations of the head of the family. The movement of general prosperity must be such as to make the establishment of children appear easy.

It is sometimes said that there are fewer children in well-to-do families than in poor families. This is true in the sense that if the income of poor families increases, the number of their children tends to diminish. But it is not really exact for all categories of rich or poor families.

Let us consider for instance the French statistics of 1906 where the families were classified according to the number of children born in these families, whether living or dead. In the families where the marriage has lasted 25 years or more, the number of children per 100 families is equal to 303 among clerks and increases to 360 among their employers, 409 among laborers, and more than 480 among fishermen and sailors of the merchant marine.

If one classifies the employers who have been married more than 25 years and who are from 60 to 70 years old, one finds that the mean number of children born in 100 families is only 305 in the liberal professions, that it increases to 347 in commerce, 370 in agriculture, 385 in all industries properly so-called.

The relative situation of employers in agriculture and industry is not the same when one considers the marriages which have lasted less than 25 years. For the marriages having lasted less than 5 years, from 5 to 14 years, or from 15 to 25 years, productivity is greater in agriculture than in industry. Everything happens as if the heads of agricultural enterprises, after having had a determined number of children more rapidly than the chiefs of industrial enterprises, stopped sooner than the latter.

The details of professions permit even a distinction between the groups of similar industries. The number of children for 100 married men exceeds 390 in mines and quarries, in the "minoterie," in the textile industries, in the enterprises of building and of transportation, while it falls to 350 and below in industries of food production, in goldsmithing and jewelry. Thus it appears that in the great industries the employers have more children and in the small ones fewer.

Among the commercial professions, the smaller number of children per 100 families is slightly higher among the butchers; it is least among bankers and heads of financial enterprises, who form a sort of transition between industrial or commercial professions and the liberal professions.

Thus, among employers, productivity seems bound, in a certain measure, to the professional characteristics, but these are rather complex. On the one hand, the intellectuality of the profession, if one may so call it, causes a small productivity, so that the number of children per family is small in the liberal professions, in the learned professions and in financial enterprises, while the manual professions have a productivity relatively higher; on the other hand, the heads of great industries seem to have a productivity higher than that of the small industries and merchants.

Two factors act in a quasi-independent way; on the one hand, the intellectual character of the professions, which leads to late marriages and creates an environment little favorable to fecundity for reasons which it is not necessary to develop here; on the other hand, preoccupation with the fate reserved for the children. In great industries, the latter will easily find employment for their abilities and will obtain without too many difficulties situations equivalent to those of their parents, either in or out of the country. In the little enterprises, on the contrary (except in special instances, such as that of butcher, where the employment of the entire family is almost a condition of success), the father of the family does not look ahead without uneasiness to the future laid out for his children.

Certain of these characteristics will be found among clerks and laborers. Among the clerks, it is the young butchers who show the greatest productivity, then the inspectors and foremen, whose productivity seems to border on that of the laborers. The smallest number of children is observed among the clerks of stores, waiters in cafés, hotels and restaurants, office and public service employees. Among the laborers, the greatest productivity—more than 5 children being born in a family founded more than 25 years—is among smaller laborers and workers in spinning mills. The lace weavers, of whom a great number work at home, have a smaller productivity than the spinners (489 per 100 families against 540 among the spinners). Moreover, in agriculture, the domestic workers of the farm, generally lodged at the farm, have 395 children per 100 families, while the field workers proper have 426.

But the industries in which the workers have less than 4 children per family are numerous. Those who have about 350 children per 100 families founded more than 25 years are makers of wooden shoes, coopers, toy makers, saddlers, tailors, printers, metalworkers, electricians, jewelers and silversmiths, various workers in commerce, drivers and deliverymen. It seems that professions of small industries, and especially professions in cities, give the smallest figures. For the masons, day laborers, and people without profession, generally employed in the cities, there are 464 children born per 100 families;

among the workers of industrial service of the state, roadmenders, etc., the productivity exceeds 390 children born per 100 families; it decreases to 360 among the police, and customs employees, etc., to 350 for workers and sub-agents of the post and telegraph service. Finally, among personal servants, it decreases to less than 3 children born per family, always for the heads of families married more than 25 years.

On the whole, among laborers and workers in great industries where the work is relatively regular and abundant, when the agricultural work offers a real stability, when the dwelling is either in the country or in industrial communities consisting of laborers of the same class, productivity is relatively high. It is lowest among the small artisans, in the trades carried on in cities, also where the profession demands physical force to the minimum degree. It is also small where the persons classified as workers are confined to the category of clerks and especially where the conditions of employment, the conditions of lodging make preferable households without children or with few, rather than housholds burdened with children.

From the preceding statements, we remember that if the workers in general have more children than the employers there are not lacking professions where they have fewer. In the second place, for one as for the other, it is the great industries which seem more favorable to productivity and small industries less favorable. Naturally here the environment exercises a certain influence, the regions of great industry being generally other than those of small industry.

The preceding observations (they are illustrated by the pictures shown in the exposition rooms of the congress) confirm, although not entirely, those that have often been made on the relation between fertility and social standing. This being at once a function of income and education, the most fortunate categories are those where education is the most refined, or where the number of children is the most limited. On the contrary, fertility would be greatest in the poorest environments, in those where the kind of life is the plainest.

If, in a general way, this observation contains a great element of truth—this is shown by the comparison of districts of great cities classified according to exterior signs of income—there are reservations which must be taken into account. There is no doubt, for example, that employers are generally more fortunately situated than their employees, and yet they have notably more children than the latter. On the other hand, employees who generally receive higher wages than laborers, have fewer children than the latter. The question has often been studied, and it is important that new contributions be brought to it.

We will borrow for new indications recent statistics of France drawn up by the aid of family bulletins filled out in 1907 by a great number of employees and workers remunerated by the budgets of the state,

departments and communes (Conseil supérieur de statistique, bulletins 10 et 11: "Statistique Générale de la France," "Statistique des familles en 1906").

These functionaries have been classified according to the annual showing of the actual emoluments and, considering only those whose marriages have lasted more than 15 years, the number of children born per 100 families has been calculated:

TABLE

Annual salary in francs	500 at most	501 to 1000	1001 to 1500	1501 to 2500	2501 to 4000	4001 to 6000	6001 to 10000	more than 10000	Average
Marriages lasting 15 to 25 years.									
Clerks	277	241	259	245	223	231	239	238	237
Laborers	329	321	293	280	254	234	...	...	307
Marriages lasting more than 25 years.									
Clerks	330	301	305	280	264	264	261	286	285
Laborers	348	363	346	329	305	240	...	...	385

When all classes are taken together, the above figures are in accord with those which have been determined with the aid of the general census, either for clerks or for laborers or sub-agents of the public service.

Comparing now the numbers of children by classes of salaries, it will be noted that, among the laborers, the number of children diminishes regularly as the salary increases; among the clerks it diminishes until it reaches a minimum for clerks earning 2500 to 10,000 francs per year; it rises for clerks whose annual income exceeds 10,000 francs.

To complete these proofs, it is proper to remark that salaries and emoluments depend in great measure on the region or settlement where each clerk or laborer lives. Change in fertility is submitted to a double influence, showing that salary is only one of the factors involved.

The influence of environment becomes evident when we observe the families of limited classes of employees scattered throughout all France, generally in the rural communes the roadmenders and the rural police. For these employees, fertility is analogous to that of the population in the midst of which they live, greater in the regions of high birth rate, smaller in the regions with a low rate.

A similar investigation has been conducted among the clerks properly so called of prefectures and *mairies*. The personnel of the employees (not composed of boys, laborers, etc) has, in general, fewer children as the number of inhabitants of the city increases; the same is true of the populations of these cities. But a comparison between the fertility of these functionaries and general fertility shows that the first is less variable than the second.

In 1901, 100 families founded more than 15 years had 199 surviving children in Paris, 228 in cities of more than 500,000 inhabitants,

266 in the smaller cities. Among the administrative employees, the corresponding numbers are 183, 198, 215, or 92 per cent., 87 per cent. and 81 per cent. of the preceding. Employees have in some degree a specific fertility which depends less on environment than that of laborers. Results analogous to the preceding are obtained when the proportional number of sterile families is determined.

Among the marriages having lasted more than 25 years, the number of sterile marriages in 1,000 marriages, varies as follows, according to annual income:

Annual salary in francs	less than 1000	1001 to 1500	1501 to 2500	2501 to 4000	4001 to 6000	6001 to 10000	more than 10000	Average
Clerks	95	86	99	113	101	111	109	101
Laborers	70	74	91	98	100	...	...	78
And the proportional number of families having had more than 7 children:								
Clerks	56	53	41	33	26	23	52	44
Laborers	95	86	75	55	50	..	..	88

On the whole, the statistics of French families permit us to see in what measure fertility is bound up with the social situation. Numerous factors intervene: for instance, the heads of enterprises in the most industrial regions of the country—the north, the region about Lyons—have many children, more children per family than many other less fortunate classes. Among the laborers, the miners of Pas-de-Calais have likewise many children in relation to other laborers. In these two cases, the parents have no fear as to the future of their children. The great employer knows that he can easily establish his; the mine laborer knows that there will always be work in the mine for his.

This sentiment becomes general when one perceives continued progress everywhere, in the agricultural, industrial and commercial movements, and in the action of public authorities in favor of education, apprenticeship, exportation, emigration and public works. Confidence in the future is then assured. It is this factor which seems to have played an important rôle in Germany after the constitution of the empire and the war of 1870. But the two factors which we have just considered, a certain courage on the one hand and a certain optimism on the other, do not suffice always; it seems useful to ward off at first the obstacles which we have recognized, that is to say, to lighten the burdens which the maintenance of children causes parents. Here it is proper to proceed methodically. Since it is a question of financial participation, it is expedient to exert the effort where it is most necessary and to seek to obtain the maximum result from the sums used. It is humane to seek that the children brought into the world be raised under the best conditions for health. It is good not to go against the

natural course of things, to limit oneself to bringing simply the spark which sets fire to the pile.

V.

These considerations tend to favor the birth rate in the country. It is there that depopulation is raging—not that the birth rate is lower than in the cities (the contrary is true)—but because of the emigration from the country to the city. This is noticed when one compares the movement of the number of inhabitants in the French censuses of different periods, either in the urban or the rural population.

In 1856 the rural population was 26 million of the 36 million inhabitants in all France; in 1911, the number had fallen to 22 million, while the total population had increased to almost 40 million. The urban has been considerably augmented—almost doubled—passing from 9,800,000 inhabitants in 1856 to 17,500,000 in 1911. It has doubled also in the class of cities of more than 10,000 inhabitants.

It is useless consequently to seek to increase the population of cities by artificial means since they increase so rapidly by themselves that there is a veritable overcrowding in great cities. But it is necessary to increase the population of the country for reasons of hygiene, social stability, and also good economy, for it is there that children cost least.

It is in the country that the birth rate is already the highest, that one will find families best disposed to have numerous children. It is stated that the birth rate increases in proportion to the altitude. But, in France at least, it is from the high altitudes that have came the strongest currents of emigration.

Children cost much less to raise in the country than in the city. In the country poverty is most disquieting, which ought to cause farmers to assure themselves of a sufficient number of children capable of helping them by their work. There the growth of children takes place under the best conditions of health, especially if a system of maternal education is instituted; there one is near the foundation of the population, and there marriages are made with full knowledge of antecedents. Even as one rejuvenates trees from the stump, so the renewing of the population, necessary to combat retrogression, ought to be worked from the base. The best always come from a vigorous stock, as the best fruits and the most beautiful flowers spring from well grafted roots. In the cities, national effort ought to tend to improve lodgings, to facilitate rapid communication which will permit the largest extensions outside the crowded areas.

In France a law of July 14, 1913, gives to every family which has at least three children less than 13 years of age a monthly allotment for each child beyond the third under 13 years, while the child is living and has not reached the age of 13 years. The communes, the departments and the state share the expense. Another law, that of June 28,

1918, gives an important share of the state power to the departments which encourage births. This participation varies in inverse ratio to the richness of the department and in direct ratio to the number of families having more than 4 children. It carries at the same time the useful premium for the maintenance of children and a premium destined to assure a life-annuity to old parents or a capital to grown children.

In cities and industrial centers, numerous patronal associations have been formed to assure to laborers and clerks allotments varying according to the number of children. The treasury is kept filled by payments of heads of enterprises proportional to the salaries paid by each one of them. Thus the industrial head has no interest in employing a bachelor any more than a head of a family. The employees of the state and those of great private enterprises receive the same family allotments added to their salaries.

Finally, the fiscal legislation assures important exemptions to heads of large families and a surcharge to bachelors and families without children.

The tariffs of income tax—"impôts cedulaires et impôts globa"—takes account of the number of children; impôt globa surcharges the bachelors as well as married men without children. The inheritance taxes grant reductions according to the number of children living or represented, and surcharges when the defunct has left no children. Reductions are given on the railroads to members of families which have many children.

A severe law has been promulgated, July 31, 1920, against abortion and the sale of contraceptive measures.

An important movement thus exists in France which cannot but be favorable to increasing the birth rate. None of the measures adopted offers dispositions contrary to the legitimate exigencies of eugenics.

Let us add that the struggle against tuberculosis and the effects of venereal disease have gained much activity since the war; numerous dispensaries have been erected so that in spite of the increase of these diseases, one cannot find, as might have been feared, an increase in the special disability of children, excepting naturally those who were born or who passed their childhood in the regions invaded by the enemy.

The decline of the birth rate is a phenomenon which has shown itself in a great number of countries. The intensity of the movement is very different in different states; its effects depend in great part on the long or short duration of time since the phenomenon commenced to appear. The causes are almost the same everywhere; the means of combatting the causes are not known to be very different, although the action of moral influences depends naturally much on general mentality. As to the other influences, the experience of France can not fail to be instructive for all nations and for all those who are interested in this still conjectural science known as eugenics.

THE TRUE ARISTOCRACY [1]

By GEORGE ADAMI, C.B.E., F.R.S.
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STUDENTS of heredity are inevitably eugenists: they are forced by their studies to recognize that men are not equal, are not even born equal save—and possibly this is all that Montesquieu had in his mind—in the eyes of the law:

> That equal justice with indulgent face
> May shine unclouded on the budding race.

They are forced to see that men come into the world endowed with different powers; that these endowments have descended to them from their progenitors and as regards any power, it may be either from the paternal or the maternal side, in such a way that the different members of one family from the varying admixture of paternal and maternal attributes themselves differ in their powers; that defects tend to be inherited every whit as much as do positive or beneficial attributes; that where any particular defect, or, equally, any beneficial property, is present on both sides the likelihood is that it will show itself in the majority of the offspring and then, it may be, in an intensified form; that, therefore, if the race is to be improved, or even to be kept from deteriorating, steps are to be taken to encourage the mating of those with the better endowments and to discourage the mating of the defectives. Whether they join the Eugenic Society or no, they are eugenists. And—though in so saying I may shock my audience—as eugenists they are, if not themselves aristocrats, believers in an aristocracy. Their desire is that for the good of the race the best shall prevail, that we shall be led and governed by them.

Now from the earliest times up to the present, man—and woman too—has sought after, and indeed experimented over rule by the best. Before the tribal or clan system became established and for long generations after, the best woman either actively by her own will, or passively, by the superiority of his, became in the ordinary course of affairs the possessor, or possession, of the best, most virile man; and if in many parts of the world for a time, for reasons that are reasonably obvious, it seemed better to establish the matriarchate and the child became a member of its mother's and not its father's family, nevertheless, everywhere that system died out from its inherent weakness. The woman might nourish and bring up, but could not protect the family.

[1] An address contributed to the International Eugenics Congress held in New York in September 1921.

The man must be the huntsman and provide the food and, what is more, must be depended upon to defend the family. And once from the family the clan system developed, for purposes of defence as for aggression and enrichment of the clan, it was essential to choose the most powerful, most resourceful, and most all-round man of the tribe as leader. It matters little whether he fought his way to the top, or found himself there through recognition of his prowess and free will appointment by the other men of the tribe. Such was the first aristocracy.

And in those simple days, seeing that this best man had a practically unfettered choice and that the most comely and capable girl of his generation was his to secure, the probability was that their children likewise would be of superior quality so that they in their turn would make the best leaders. Wherefore, through experience men came first to be prepared for and then to accept a hereditary aristocracy, acknowledging the existence of first families and finding it for the good of the tribe that an Amurath should an Amurath succeed, and Harry, Harry.

Now entertaining as it would be, more particularly here in New York, to trace the further development of this hereditary aristocracy until it came to include emperors and kings, and a succession of grades of nobility, and reached its fullest elaboration in the feudal period, I am not going to do this. All I want to impress upon you is that the elemental idea of an aristocracy is sound and natural, but, granting this, that, thus far, however successful we may have been in the practical application of the idea to the establishment of the four-footed "aristocrats" of the turf and trotting ring, and in the breeding of animals possessing superlative speed or power or form or mass of flesh, be they racers or Clydesdales, greyhounds, red Berkshires or Plymouth Rocks, we have, to speak frankly, made rather a mess of it among ourselves, until to many the idea of a hereditary aristocracy of any order is intolerable, an opinion strengthened by the observation that those who most loudly proclaim their aristocratic relationships are most often such as those aristocratic relations least care to acknowledge, the said claimants having family and beyond that nothing of worth. Wherefore one has come to doubt the worth of family.

And yet so perverse is humanity that those to whom aristocratic régime is most abhorrent cling in their innermost hearts to their family tree and either pride themselves on the possession of this or that ancestor or upon the mingling of this or that stock into theirs. I may note incidentally that here, in this great republic, genealogy is pursued to an extent unknown elsewhere. While those unfortunates who, to put it generously, can not look down their family tree, look up to the fair tree that is to spring from their loins and see its future growth to overtop its neighbors.

In other words, the love of good family, either as something already attained or as something to be attained, is inherent in the human race. We seek higher things. Through all the centuries we have been eugenists in principle, even if in practice we have made a painful mess of it. For in practice all these centuries we have mistaken accidentals for fundamentals, have elevated immediate advantages above future well being. With royal and princely families the stamina and capacity of the bride to be has been the lesser instead of the prime consideration: the choice of consorts has been limited to a parlous not to say sinister extent, and the political importance of alliances between royal families has too often led to matings that could but result in a deteriorated progeny. And where, as in France, among the people in general, there is a well established opinion as to the importance of carefully selected matings, there also the quality of the stock has been subordinated in general to the size of the "dot": more has been thought of the property that will come into the family than of the richness of the blood that will be commingled. The results on the whole have not been any more satisfactory than have been those of the "mate as you please" system which obtains in Anglo-Saxon countries.

Now, with the twentieth century, we have awakened to the fact that the principle of "laissez faire" is as pernicious in the matter of marriage as it is in politics. Our eyes have become unwillingly opened to the fact that with the improved well being of the people and the very material lessening of the death rate it has come to pass that the multitudinous children of defectives and those who both physically and mentally are of the lower order are forming the bulk of our population, since those who are pre-eminent, intellectually and bodily, marry late and have small families. In other words, the social conditions of the present day are such as to favor the preponderance of what are from every point of view the lower classes, the survival of the unfit and the inevitable deterioration of the race.

But here is the difficulty. Among what we regard as the lower classes are included not a few families of good quality, both mental and physical, which through accident, as for example, illegitimacy, or the fortunes of war, or the premature death of the breadwinner, are in poor circumstances, occupying a menial position. Circumstances have been against them. Thus it follows that from time to time we encounter men sprung from the ranks who, given the opportunity, come to the front and make their mark in the world of commerce or of intellect. Even when the feudal system was at its height and when caste was most repressive, men of this order could occasionally, although rarely, force their way to the front, either through the Church (although then they still more rarely founded families) or through their military prowess as leaders of mercenary troops, or, like the Medici,

through the city guilds and the power of the purse. The last, industrial, century, with its broad middle class forming a bridge between the working and the ruling classes has seen this becoming so frequent a phenomenon that it, with the equally obvious but, I think, less frequent examples of the decadence of families that for generations have been held in high repute, has led to what was a wide spread conviction, namely, that birth and breed count for little and that fortunate up-bringing and environment are the more important factors in a man's success. Even to-day this opinion is held by a large number.

Now I am not going to discuss the still debated problem as to the extent to which environment modifies the individual and so the family and the race. I am going to satisfy myself with the well established principle or biological law, that by cautious selective mating, qualities of very various orders, in man, equally with other animals and with plants, can be strengthened and intensified. I do not say that they are capable of indefinite expansion. We have, indeed, no proof that this is so. Rather the evidence indicates that we can by selection lead up to what I may term optimum development—development best suited to the size and state of other parts and properties of the individuals of any particular species in its particular environment. Developments in excess of this proper correlation may, it is true, show themselves in individual members of the species, but, even when mated with others showing a similar excess, the progeny do not exhibit the excess. Let me give an example of what I mean. By careful selection, proper feeding and surroundings, we can gradually improve the laying properties of various breeds of fowls, but this only up to a certain point. Occasionally, it is true, we encounter individual pullets of a particular breed who yield it may be ten or twenty eggs per year above this established optimum. But now it is found that if we mate the male and female progeny of such excessive layers, they only produce at most the optimum, indeed, most often less than the optimum. It is as though the exhibition of a particular property, above a certain limit, exhausts the individual in other directions and leads to deterioration rather than to improvement.

I am not suggesting therefore that, the environment remaining unaltered, man, as man, is by selection capable of indefinite improvement. The most I urge is that to-day so large a proportion of human individuals is so far below the optimum that there is vast room for improvement: that under modern conditions through the larger families of the unfit the race is deteriorating and not improving, and that it behooves us to take active measures whereby to encourage the selective mating of the best and the production of those endowed with sound and useful qualities.

Now the function of societies for the promotion of eugenics is, I

hold, to promote this better mating, but, if I may speak bluntly, I am impressed with the fact that they have begun at the wrong end. Passing in review the pages of the volumes of the *Eugenics Review* what I find in them is, with all due deference to the high-minded ideals of the leaders of the movement, a vast amount of spade work in the establishment of the broad principles of heredity, a profound appreciation of Mendelism, sundry lamentations of latter day prophets, such as the most witty, albeit most doleful, dean of St. Paul's, upon the downfall of Jewry, or more accurately, the sure and certain deterioration of humanity, the qualified approbation of sundry destructive procedures such as restriction of criminals and segregation of defectives as adopted by certain states, but with this singularly little constructive policy; or if I may so express it, a ha'porth of bread to an intolerable deal of sack.

Now possibly the leaders in this movement are acting most wisely in devoting their time to making sure the foundations, and in the first place driving home to people the extent and the dangers of national degeneracy. Possibly the fear of degeneracy is in this matter of eugenics the beginning of wiser courses. Nevertheless, I can not but feel that usually in this world with the planning of foundations there is requisite some considered design of the building that is to rise upon those foundations, and that design is here largely wanting.

As for what I have just termed the destructive procedures, I have strong doubts as to their politic value. Some experience of the world has taught me that while a majority of mankind is law-abiding and will obey commands of the order of "Thou shalt not," there exists a very considerable minority to whom such commands act as a stimulus or incentive to set them at defiance. Grave as are the consequences, prohibition of marriage on account of the existence of venereal disease in one or other of the contracting parties will not put a stop to such marriages; nor will segregation of the feeble-minded prevent those feeble-minded seeking or consenting to illicit conjugation whenever occasion arises. The ordinary every day individual, thinking only of matters of the moment and careless of the future, will not hesitate to transgress laws which interfere with his liberty. The only laws interfering with personal liberty that are generally kept are those the transgression of which is followed by a personal penalty, such as that of the judicial murder of those committing murder. Public opinion is not as yet ripe for the infliction of castration upon those who, for instance, enter into the married state while knowingly sufferers from venereal disease, richly as they deserve it.

What is more, even granting that by these and like methods we reduce the number of defectives, thereby we only advance the average quality of the race: we do not actively increase the number of those of

first-class ability. This I am glad to see is being recognized in the United States.[2] The need is to promote the propagation of the best in the race. And it is to show how this can be accomplished that now I want particularly to direct your attention.

In the first place, I would lay down that encouragement is more effective than punishment; that the "thou shalt not's" of the decalogue and older dispensation have given place to the blessing of the positive virtues of the new; in the second, that the war has supplied the solution.

Making enquiries as to the proportion of rejections from the British Army, to compare with the Canadian figures, it was my good fortune to be promptly appointed by my late colleague at Montreal, then minister of national service, now British minister in Washington, on the scientific committee of the Advisory Council of his ministry—and as a member of that committee it fell to my lot to oversee the analysis of the physical state of the manhood of Great Britain in the last year of the great war. That you should understand the significance of this analysis and of the figures presented to us it is necessary that I enter into certain explanations.

I may remind you that service in the British Army had at first been voluntary and then as the situation and needs became more and more grave, first conscription became what I may term persuasive with "combing out," and then in 1917, became generally compulsory, all able-bodied men between the ages of 18 and 51 being called up. In the middle period, large bodies of men employed in industries of primary importance to the nation had been directed not to join the colors. Their industrial services, indeed, were deemed of such importance that then began that undue augmentation of wages which has been at the root of the present economic trouble in Great Britain.

For generations prior to 1914 men volunteering for military service had, prior to acceptance, to undergo medical examination into their physical fitness. Hitherto, this had been conducted by adequately trained officers of the Royal Army Medical Corps. The war with its sudden augmentation of the army and need for battalion medical officers and ambulance and hospital corps at the front and at the base found the corps all too small. Every well-trained man belonging to it was needed at the front along with many times the number of surgeons and practitioners enrolled out of private life. Inevitably the younger and more vigorous of these joined the army and went overseas, leaving behind the older and less vigorous who now were called

2 "While the need of cutting off defective and degenerate lines is becoming widely recognized and is being met with legislative enactment, there is as yet little organized effort to direct the evolution of lines among our mediate and superior classes."—W. E. Key, *Journal of Heredity*. 11. 1920. 359.

upon not only to take over the patients and practices of their absent colleagues, but also, without adequate training, to undertake for the government at different centers throughout the country the routine examination of would-be recruits for the army. The results were what might be expected. Many were passed for service who were totally unfitted, who subsequently had to be weeded out of the army at heavy cost to the nation; there were repeated cases of wide and inexcusable differences in the findings of successive examiners, damaging criticisms in the public press, and development of a feeling of public insecurity. As a result the government determined to take from the Royal Army Medical Corps the responsibility for examining recruits, and, under the Military Service Act of 1917, it withdrew the matter of "categorisation" from the army, placing it under the control of the minister of national service, who forthwith proceeded to organize the physical examination of the men called up, placing the task in the capable hands of Dr., later, Sir, James Galloway, and a small but carefully selected committee.

The country was divided into regions, commissioners were placed in charge of each, with deputy commissioners and a staff under them. The deputy commissioners were brought together and trained so as to employ common standards and arrive at a common agreement regarding the categorisation of border line and doubtful cases: a clear and admirable code of directions was placed in the hands of every member of the new boards and, in short, every endeavor was made to conduct the physical examination from one end of the country to the other under a single standard. Thus, at the end of 1918, it fell to our committee to direct an analysis into the results obtained from the physical examination of close upon two and a half million men conducted under these standardized conditions.

Here it will be out of place to detail the difficulties encountered in analysing and weighing the figures before us. Those are to be found discussed in the Government Blue Book containing the report of the committee drawn up by Dr. H. W. Kaye as secretary to the committee.[3] Nor again am I going to dwell upon the alarming picture this report disclosed of the wide spread physical unfitness of the adult male population of Great Britain. That is apart from my present object. What is to the point is that for the purposes of arriving at the significance of the figures under review, Professor Arthur Keith, F.R.S., the distinguished anatomist and anthropologist, who was a member of the

[3] Report upon the Physical Examination of men of military age by National Service Medical Boards from November 1, 1917, to October 31, 1918, London. February, 1920. Those to whom the British Government publications are not easily available will find an abstract of some of the main findings of the report in the *Lancet* (London), Vol. 1, 1920, pp. 557, 726 and 780.

committee, pointed out that the established "categories" of the army, A, B, C, D,[4] could be translated into "Grades" I to IV in the terms of the polygon of frequency.

Let me explain. It was found that a thousand Cambridge University students, measured for stature, arranged themselves in a significant manner. (The same has been found true of other exact human measurements). In this particular set of men, those measuring more and less than this tailed off inch by inch on either side of this mean with striking symmetry.

There were roughly, within a few digits, as many men of stature 1 inch below this mean as there were men 1 inch above, and, from this mean of 5 feet 9 inches, those more or less in height formed classes

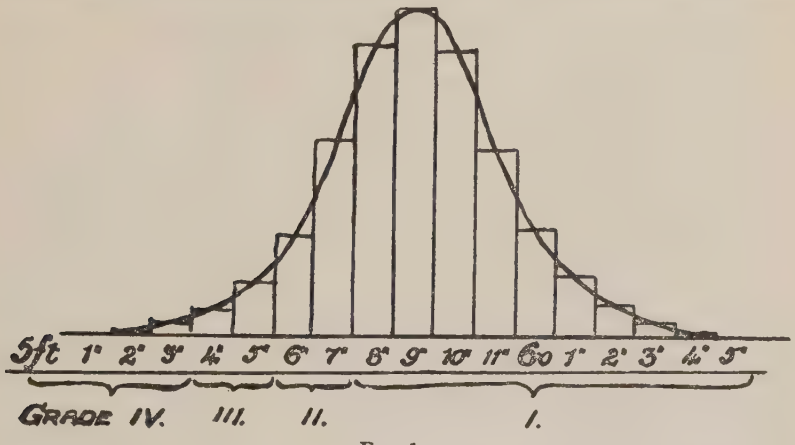


FIG. 1.

tailing off in a curiously balanced manner. On such a "polygon of frequency" as shown in the diagram one can construct a curve of frequency.

Keith pointed out that the mean class (that of 5 feet 9 inches) together with all those above the mean and the class just below the mean, together constitute 70 per cent. of the total, and he assumed that the combined measurements employed to determine a man's physical fitness should follow the same general law. Along these lines he laid down that the active service group should include all average men and those

[4] Category A. Men physically fit for active service at the front.
" B. Men able to undergo a considerable degree of physical exertion and with fair hearing and vision, but in consequence of partial disabilities unable to stand severe strain; fit for any form of service overseas save active service at the front.
" C. Men who in consequence of physical disabilities could not undertake marching but could be employed for the less arduous and sedentary occupations.
" D. The rejected, unfit for any form of military service.

above the average in physical fitness together with those just below the average, and that therefore we should expect in a reasonably healthy sample of the male population:

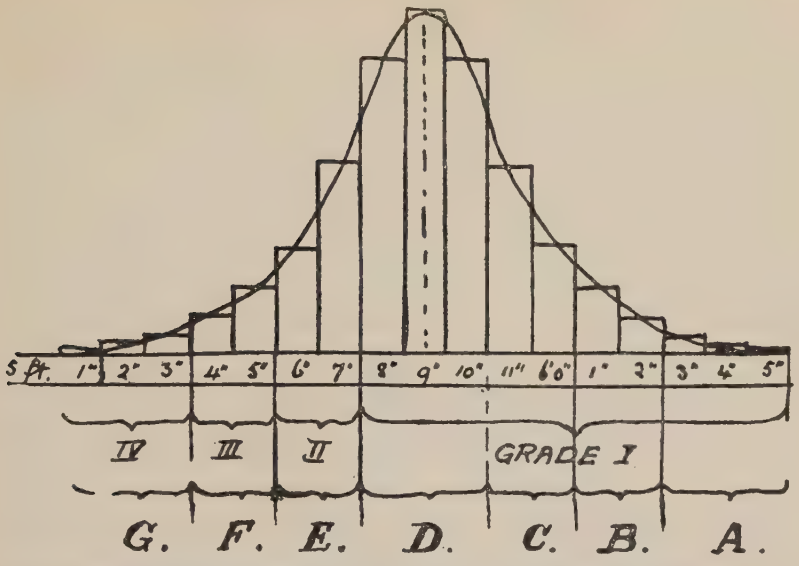
700	out of each 1000	should be	"A"	men, belonging to	Grade	I.
200	" "		"B"	" "	Grade	II.
75	" "		"C"	" "	Grade	III.
25	" "		"D"	" "	Grade	IV.

As a matter of fact these index figures of Professor Keith showed themselves close to the mark and most useful for purposes of comparison. Certain mining and agricultural districts indeed yielded well above 700 per 1,000 Grade I men. Scottish miners between 18 and 21 years of age yielded 80.62 per cent., young adult Scottish ironworkers 86.18 per cent. But while in general mining and agricultural districts yielded the expected 70 per cent. or thereabouts, the great towns afforded conscripts gravely below the standard. I take the 18-year old group as that which should physically be fittest, least affected by the deleterious influences of industrial and commercial or sedentary occupations. Even in this most favorable class, studying the results obtained in different areas, cities like Liverpool and Birmingham yielded 49.5 and 36.0 per cent. Grade I men, respectively: they were lower in the big manufacturing towns, for example, 1,000 youths in Burslem yielded only 270 in place of 700 physically fit for active service, in Dudley only 219. So serious a state of affairs was disclosed that it is of first importance to the nation to discover whether this is due to progressive deterioration of the town-bred and industrial stock or whether the effects of unfavorable environment on the growing individual are wholly responsible. For myself I cannot imagine the stunted and anemic mill-hands of Lancashire bringing forth offspring which under the most favorable environment could develop into men and women of full stature and all round physical capacity.

This, however, is away from my immediate point. What is of first importance is that the report of the Ministry of National Service has demonstrated that it is possible to establish a series of tests for the exact and uniform measurment of physical capacity and, having these, to grade those who undergo the tests into a succession of clearly defined classes.

For eugenic purposes, however, it will never do to take over the national service grading. We do not want to clump together the average, those just below and all above the average into one common group. That was well enough for determining men capable of becoming front line troops. But we need to select the best, not the average. Thus as I suggested three years ago,[5] just as the army for its purposes recognized

[5] "The Physical Census," an address delivered before the Medical Society of London, 25 November, 1918, and printed in the *Transactions* of that Society, as also in the *Canadian Medical Association Journal*, September, 1919.



three categories below the mean, so for our purposes we might well establish, as shown in the diagram, three classes above, making in all seven classes.

In this way Class A would contain the very pick of manhood, a select class of some 2 per cent. of the whole body, men of exceptional all round physical development; Class B, men thoroughly well developed, who might, only in some one respect such as stature, fail to be included in Class A; Class C, good all-round men distinctly above the average; while Class D would represent the large group of ordinary average men, and Classes E, F and G would correspond with Grades II, III, and IV of the National Service system (Army categories B, C, and D.)

This, however, is only half the matter. Neither Great Britain nor any other European nation made any attempt to pick out from the start the men most likely to develop into good officers and non-commissioned officers. For that they depended upon the actual test of army conditions. In other words, not a single European nation applied any test of intellectual capacity. It was left to the United States to apply this eminently rational procedure to the army she raised for overseas service.

Scarcely had war been declared by the United States in the Spring of 1917 before the American Psychological Association brought together its members to consider how they might serve the country in the emergency.

It should be explained that the pioneer work of the late Professor Alfred Binet, of the Sorbonne, had made a greater impression in North America than it had in France or Europe in general. In 1905 Binet had shown that it was possible to devise reliable tests of mental capacity applicable for each year of age of the developing child, so that, ac-

cording to the way a child responded to the tests, it might be accurately graded—e. g., a child of the actual age of 10 years might be shown to have the mental capacity of, it might be, the ordinary child of 12 years of age, or, on the other hand, only that of a child 5 years old. This method had been extensively tested by various American psychologists, more particularly for the elimination or segregation from the public schools of those mentally defective. Important advances in the methods of testing and evaluating the tests had been represented by the Goddard revision of the Binet scale, the Yerkes-Bridges Point scale and the later and fuller Stanford revision of the Binet scale, for which Terman was largely responsible.[6]

The chief purpose of the psychological assistance originally offered to the Army Medical Department in the Spring of 1917 was the prompt elimination of recruits whose grade of intelligence was too low for satisfactory service. But when in the autumn in order to test the value of the methods of the committee they were applied to enlisted men of all orders in four selected cantonments the results obtained tallied so closely with the more slowly acquired judgment of the officers in command as to warrant the recommendation "that all company officers, all candidates for officers training camps and all drafted and enlisted men be required to take the prescribed psychological tests" and in January 1918 the recommendation was acted upon. Every soldier was tested and assigned an intelligence rating on the basis of a systematic examination. Through this system men of superior intelligence were selected from the first for advancement for special posts and particular types of military duty, or recommended to enter military training schools. A school for training in military psychology was established, and by Armistice Day, in November 1918, the psychological personnel attached to the Army Medical Department had risen to 120 officers and 350 enlisted men together with some 500 additional clerks engaged in the examining service in thirty-five camps throughout the country. The tests had been applied to 1,726,966 men, of whom 41,000 were officers; 7,800 men had been recommended for immediate discharge on account of mental inferiority; 10,014 had been recommended for labor battalions, and other service organizations on account of low grade intelligence. Men qualified to be non-commissioned officers and candidate-officers on the basis of satisfactory intelligence scores were picked out within forty-eight hours of their arrival in camp.[7]

[6] There is abundant American literature on the subject, for which consult more especially the "Manual of Mental and Physical Tests" by Whipple, and "The Measurement of Intelligence" by L. M. Terman, (Houghton, Mifflin Co.) Boston.

[7] For further particulars see "Army Mental Tests" compiled and edited by Clarence S. Yoakum and Robert M. Yerkes, New York: Henry Holt and Company, 1920.

The new procedure must have proved itself eminently serviceable and practical to have become applied universally to all recruits within six months of its experimental introduction into the army. As a matter of experience, the rating awarded to a man as a result of the tests was found to furnish a fairly reliable index of his ability to learn, to think quickly and accurately, to analyze a situation, to maintain a state of mental alertness, and to comprehend and follow instructions. The score was little influenced by schooling or, more accurately, it was so influenced,[8] even though at the same time some of the brightest records were made by men who had not completed the eighth grade of the U. S. public school system.

It is a not uninteresting coincidence that the American scale was worked out in percentages, 100 being taken as the highest available mark, and that here also seven classes were recognized, namely:

A. (rated 96 per cent. and over). Very superior intelligence—usually earned by from 3 to 5 per cent. of a draft—men of pronounced intellectuality of the high officer type (if endowed also with capacity for leadership and qualities which admittedly are not revealed by the standard tests).

B. (80-95 per cent.) Intelligence superior but not exceptional. Obtained by 8 to 10 per cent. of a draft—men of the officer type and many non-commissioned officers.

C. + High average intelligence, comprising from 15 to 18 per cent. of all soldiers, with a large amount of N. C. O. material. With power of leadership men of this grade are fitted for commissioned rank. (The three C groups include those grading from 40 to 79 per cent.)

C. Average intelligence, the main mass (25 per cent.) of soldiers. Excellent "private" type.

C.— Low average intelligence (about 20 per cent. of material). Men satisfactory for work of a routine nature.

D. (20-39 per cent.) Inferior intelligence (15 per cent. of all soldiers). Fair soldiers but low in rank. Slow in learning with little initiative, rarely attaining higher rank than "private."

E. (0-19 per cent) These along with D— are of very inferior intelligence. D— men were considered fit for service. Some E men were placed in labor battalions but most were rejected. D— and E men were below ten years in mental age.

It deserves emphasis that the tests only indicate intelligence. They do not measure loyalty, bravery, power to command, or those emotional traits that make a man "carry on." Nevertheless, next to physical fitness, intelligence is the most important single factor in military efficiency.

[8] Thus while stating (p. 22) that the rating was little influenced, Yoakum and Yerkes give a table showing that there was a steady increase in intelligence in the students of the successive years at the University of Illinois; 91.4 per cent. of the freshman class were rated in the two topmost grades, as compared with 92.3 per cent. of the sophomores, 94.1 of the juniors and 95.9 of the final year.

Thus, to come to the point, the great war has in one respect been of service: it has afforded material for testing on a great scale and demonstrating the possibility of devising accurate and satisfactory methods of measurement of physical and intellectual capacity. Henceforth there can be no question as to the practicability of establishing standards of efficiency and quality. Nor is there any reason why these tests be not applied to women as to men. The method has been tested and found of proved value.

And what I would urge is that here at last we have before us the obvious line of practical work for eugenic societies and the eugenic movement in general. Encourage the best! Either organize, or make the state organize in every district a trained staff provided with a well-equipped set of rooms for the routine testing of every young person whether male or female, who has reached the age of eighteen years. I say eighteen because, while intelligence does not, so far as we can see, improve beyond the standard which some are capable of reaching at the age of sixteen, undoubtedly there are slow developers whose intellectual capacity, below normal at this life period, improves after the age of sixteen, while in general physical capacity is at its best at the age of eighteen, and from other practical considerations this latter age is the best for purposes of record.

Do not make the tests compulsory. What indeed is the need to trouble about the average man or woman. We want to pick out the best in the community. And having picked them out publish their existence in the world. Establish an annual record of all the A I youths and maidens of the year, "A" standing for the first class in physical fitness, "I" for the first class in intelligence. Nay, I would say publish the list of all who attain to "A" and all who attain to "I" standards. There are positions in which physical fitness is sought after irrespective of mental capacity, and vice versa. Like considerations might favor the publication also of all the "B" and the "2" classes, for both are well above the average.

Think of the effect of such a publication. Think of the start in the world it would give to a man or woman to be able to refer to his or her record as belonging to the A 1 class; think of the status it would give him or her for the years to come, of the preferential treatment that would be afforded when applying for posts. Consider the preference the A 1 man or woman would have in marriage, how parents before giving their consent would require that he who sought their daughter's hand should produce his eugenic society certificate and show where he stood in physical and mental capacity; of the advantage the A 1 man would have in seeking the hand of a desirable damsel. Think how in years to come these annual publications would establish the good strains, the desirable families with which to become associated, how in short they would become the human stud book.

But, it may be objected, the man who at eighteen is rated as A 1 might from a variety of causes—tuberculosis for example, or grave accident such as fracture of the skull, or acute infectious disease, or venereal disease, or overwork, mental or bodily, fail to maintain his rating: the fact that in youth he was A 1 is no assurance that by thirty he is not an undesirable. Quite so. But this is by no means an insuperable objection—once the published record appeared, the first-class man would come to ask to have his rating renewed so long as he continued to be first class, say every five years, at 23, 28 and 33 years, and if he could not produce certificates of continued efficiency this would tell against him, unless he could give a satisfactory explanation of the cause of his reduction in rank.

Now the indications are that there is a natural, or, under present methods of life, an expected reduction in physical efficiency after twenty-five years of age and of mental alertness after thirty-five or so. These would have to be taken into account.[9] So far we do not possess data sufficient to establish what may be termed the normal curves of physical and mental efficiency for successive age periods after eighteen.[10] The accumulated statistics of A 1 men and women would supply material for the establishment of a table of what may be termed age-efficiency, mental and physical, for successive years of age from fifteen to fifty.

Here would be the ideal Debrett—here the establishment of a veritable aristocracy of the country, personal and hereditary. I ask you to think over it. The scheme is not impossible. It only needs to be started to show its usefulness. Nay, more, it would be self-supporting. Men and women of good quality would gladly pay a moderate fee to cover the cost of the examinations and for the cost of announce-

[9] See Adami, Loc. Cit.

[10] A beginning has been made. The Bulletin of the National Research Council on the "Intellectual and Educational Status of the Medical Profession in the United States Army" by M. V. Cobb and R. M. Yerkes (Washington, February, 1921) shows (p. 483) that there is no significant decrease in intelligence rating (of officers) rating from 20 to 26 years but thereafter to the age of 60 there is a marked decrease. The relations of intelligence to age of 95,742 medical officers examined at Camp Greenleaf gave:

Age of 25 (303 cases)	277
" 30 (334 cases)	258
" 34-35 (257 cases)	262
" 40 (305 cases)	255
" 44-45 (241 cases)	235
" 50-51 (131 cases)	223
" 54-55 (63 cases)	212

These figures indicate a slow descent from 25 to 35 and after that a more rapid one.

ment and publication of their superior merits. Compare the cost of encouragement thus of the best to that of hunting out and suppressing the unwilling worst. Again, I say it only needs to be taken up seriously and started to demonstrate its value and desirability. Here at last we aid and encourage the improvement of the national stock, the advancement of the quality and well being of the nation through the establishment by scientific and democratic means, irrespective of wealth and influence, of the real aristocracy of the nation.

SCIENCE IN FRANCE

By Professor PIERRE BOUTROUX

THE very title of this article seems to imply two preliminary assumptions which many modern readers will be inclined to question. First, that in this time of technical achievements and highly specialized work, there still exists such an entity as "Science," distinct from the various sciences. Second, that when industry, commerce, politics, even literature, become more and more international in their scope and character, science may still be considered as some sort of national enterprise.

I have no intention to ignore the questions thus raised. But the best way to throw some light on them is precisely, I think, to fix our attention on some particular case, on some concrete country, and to observe whether the different scientists of that country have or have not something in common, some definite standards and ideals which may be called their own.

Such a problem has little or nothing to do with the enumeration of the notable discoveries achieved in such and such country. A true discovery, being the mastering of some new piece of universal truth, *must* have an objective and therefore an international value. The greater the discovery, the more impersonal it is. So that the prevailing custom, which makes us call discoveries and laws of nature by the names of persons is, in point of fact, just as misleading as it could be.

But the objective discovery is not all of science. It is only the end of it, the result obtained by scientific work, that is, by human activity. Furthermore, any single discovery has to be linked and compared with other discoveries and hypotheses: as soon as it is acquired, it becomes part of a theory which is largely contingent and human. Now, on the one hand, it is a well known fact that there is no sure method, no marked and traceable path for obtaining scientific discoveries; only by trying and trying over again, by toiling, approaching questions from various sides, opening our minds to inspiration and intuition, may we hope to fall upon the idea which will lead us to discovery. *Theories*, on the other hand, are always provisional and changeable, and there is no absolute standard to fix their value. This being so, is it not to be expected that the type of education a man has been given, the habits of mind which he has acquired in life, the models which he finds before him, the general ways and inclinations of his surroundings, will have a notable influence on his methods and on his work?

There are surroundings, there are countries in which, for some reason, some kind of work is more likely to succeed than in others, in which some discoveries have a greater chance to be arrived at, in which some types of scientific system are more likely to spring up. The influence so exerted is felt even by foreigners and it is worth while studying it. I said a moment ago that to associate names with discoveries is a task void of any real interest. But, on the other hand, it is not uninteresting to learn that the Wright brothers achieved decisive success and gave a great impetus to aviation while they were working in France. To take a more convincing example, it is interesting to know that the great scientist and philosopher of Hanover, Leibniz, did come to Paris as a young man and found there the inspiration and the ideas which led him to his first discoveries.

What was it that Leibniz and many other scientists of his time and other times have found on French soil more than they did elsewhere? What are the qualities that have made French scientists often successful and given them followers all over the world? On the other hand, can we trace any characters of scientific *theories* which are especially appreciated by the French and are generally apparent in their productions? Such are the questions which I would try to answer, considering first the tradition of scientific work in France, and second its present condition.

* * *

The traditions upon which modern French science is based were laid down during the first half of the seventeenth century.

This does not mean that science was not an important factor in ancient French civilization. As a matter of fact, the part played in the first revival of science by the University of Paris, the oldest in the Western World, has been exceptionally brilliant. However, the merits of the work then done are not exactly of the type which can be contemplated from a national standpoint. Science in the Middle Ages was highly international, more international than it has ever been since. Besides, the brilliant era started by the old University of Paris was followed by a period of comparative obscurity. Science was again at a standstill until the revival of the study of the original Greek treatises gave it a new impetus. Later still came the time when a reaction against too close an imitation of the Greeks was deemed desirable and when it became apparent that new ways should be tried. Then it was that the national character and national ideal had an opportunity to show themselves. This happened in France at the very moment when French literature, French art, French culture generally, reached their highest point. The time of Corneille, Molière, Bossuet is also the time of Descartes and Fermat. There is a deep significance in that fact, and it is not through a mere coincidence that a man like Pascal

was as famous as a physicist and mathematician as he was as a moralist and as a writer. Pascal, by the way, might be regarded as a fair representative of the French scientific spirit of his time. Descartes, however, is the leading figure. Descartes stands first, not only because his influence has been the widest, but because he was the man who realized fully that the old conceptions were to be changed radically. He was the man who had the clearest and most prophetic vision of a new type of science.

But, before trying to define Descartes' position, I wish to make a few preliminary remarks.

In the system of knowledge which forms a science, two kinds of elements are fundamental: First, the logical deductions or constructions, which combine abstract principles, notions or statements; second, the facts, which are either experimental facts or such facts as may be found in pure mathematics.

The logical aspect of science had been dominant in the work of the Middle Ages. During the later period of its evolution, at least, scholastic science was based chiefly on logical constructions. Such a science will not be worthless if it happens to rest upon solid foundations. But it is likely to become, in most cases, a purely formal and abstract system, which will care little about the value of its material as long as its deductions are correct and consistent. The weakness of scholastic science was that its aim was not definite, its development was not guided. Logical combinations, worthless for any practical purpose, without any appeal to human intelligence at large, may be piled up and piled up and form an endless chain. Huge books have been filled with them, the aspect of which is somewhat terrifying nowadays. It took a man's life to write one of these books and years to study it. And the trouble was that scholars were actually compelled to read all those books; for, to prolong the chain of science, one logically had first to go through the whole length of it. So that scholastic science could not but soon degenerate into hopeless erudition.

The case would be very nearly the same for a system of knowledge based on the second kind of elements, which we have discriminated in science; namely, *facts*.

In the age of Descartes, to be sure, no attempt to build a science on facts only had ever actually been made. Experimental work was still in its infancy. However, a man like Descartes, who was fully aware of the value of such work, could not but perceive the danger which a science based on experiments would have to face. The danger was to pile up facts without the guidance of reason. Such a task would be entirely indeterminate just as is the piling up of logical propositions. It would be endless, and a man might consume his life in this task without becoming any wiser.

Notwithstanding this danger, the kind of science to which I am now alluding is still favored, in our own time, by a few scientific circles.

Arguing that theory is always open to doubt, while a fact in itself, is something solid, there are men who believe that the scientist's activity should all be concentrated upon this one aim: *to acquire new facts.* The men who are promoting such views do not always realize that *their* science—although very different as to the materials from the old scholastic science—will be exactly the same in spirit; or rather it will be the same in the lack of spirit. Accumulation of particular truths, but no leading principle, no illuminating light. Erudition exalted. Discrimination and intelligence secondary. A cumbrous, aimless, hopeless and dead science.

It is against such an ideal, such a conception of science that René Descartes took his stand.

Descartes was endowed with a revolutionary turn of mind. He had, as far as science is concerned, no respect whatever for tradition. Even Greek geometry, which we consider so perfect, is condemned by him. He mentions that all scientific productions of former generations are entirely worthless.

All that we know of Descartes, indeed, is in sharp contrast with the figure of the old schoolman.

First of all, Descartes is *not* a professor.

In the Middle Ages and later, most of the students of science were engaged in the teaching profession. Secluded from the world of action, they were anxious not to let any outsider intrude into their field of knowledge. They jealously closed the doors of science in the face of all Philistines.

Not so with Descartes. How could a man with his temperament be contented with university routine? From his youth, Descartes had felt inclined to live an active, independent and dangerous life. He travelled all over Europe, he was a soldier and fought in Holland and Germany. Later he moved from one place to another, not being able to settle anywhere until he met with a premature death in Sweden.

These facts we have to bear in mind if we want to understand, not Descartes only, but all the great French scientists of the same time. Fermat, who is considered by many as the most prominent mathematician of that age, was not a university man either, but a judge at Toulouse. Desargues, famous among geometers, was an enginer. Pascal was a private gentleman, self-taught.

The lives of all these learned men were widely different. And yet they all had something in common and belonged to the same class. They represented the type which the French of the seventeenth century called an *honnête homme.* To all of them the scholar of the scholastic type is equally abhorrent. He is the man who has been so fitly

ridiculed by Molière, in the *Thomas Diafoirus* of the "Malade imaginaire." Diafoirus is a reputed magister, who has much dialectic ability, but no judgment. The *honnête homme* does not boast of any special acquirements or training, but is richly endowed with good, simple, common sense.

On that notion of "good sense" (*bon sens*) is based the whole Cartesian theory of science. According to Descartes, *bon sens* is a common property, a common gift of which all men have their share. It is the power which men have to act and think not only in agreement with their bodily experience and with the laws of logic, but in agreement with reason.

From this view an obvious inference follows Science shall not be the exclusive property of specialists any more. But it will be open to laymen; and the layman will even do better than the specialist because he will not indulge in formal erudition and bluff, but his aim will be to make science clear, simple, well ordered, intelligible to any sensible human being, and to make it a living, instead of a dead thing.

The chief characteristics of such a science may be summed up as follows:

First of all, as we just said, science will be *simple*. A scientific system which would lack simplicity would be wrong.

This, I admit, will be considered by many as a bold and rather imprudent statement. We certainly agree with Descartes when he condemns those conceited scholars who are prone to make science complicated just for the sake of appearing as great men in the eyes of ignorant people. But why, indeed, should we believe, and believe on principle, that a science explaining the laws of mechanics, physics and other natural phenomena, is bound to be simple or can be simple?

To confirm such an opinion, Descartes feels compelled to build an elaborate metaphysical system which, according to philosophy, is now a thing of the past. As a scientist, however, we may think that Descartes was right; for the conception of science, which, after many trials, mankind has finally reached, seems to vindicate his statement. Not that science will be just as simple as Descartes thought. But we have come to regard science largely as an arbitrary construction which justifies its course and its hypotheses chiefly by being convenient and simple.

The second characteristic of Cartesian science is that it will *not* be, in any respect, a collection of data or propositions. As we don't know beforehand what data, what deductions, what theorems will be needed for future scientific or practical purposes, therefore, Descartes would say, it is quite useless to gather and hoard such commodities in advance. What we need is a *method* which will give us the power to get the data and to get the propositions as soon as we require them.

A third fundamental characteristic of science—which is not explicitly defined by Descartes himself, but follows from his conceptions—relates to the sort of work which the scientist of high rank has to accomplish, and to the special abilites that are required of him.

Since the task of the scientist does *not* consist in piling up data and reasonings, but in presenting a few clear, comprehensive and far-reaching notions, it follows that this task will be chiefly one of choice and discrimination. Not all the things that are true are useful and worth saying, but only a few, which the intelligent man has to pick out and to discriminate

How will such a discrimination be carried out? There is no ready answer to this. The question is one for intuition, for intelligence and foresight to decide. To choose the fundamental notions or *hypotheses* on which a scientific construction will be based, to select a *plan* for this construction, to find out the *tests* which will help to compare the construction with experiments, all this forms the most delicate part of the scientist's task. And the most important part too. Between the man who is only capable of deducing and combining ideas or data and the man capable of making the right choice, there is the difference which divides scientific ability from genius.

Let us finally mention a fourth characteristic of Cartesian science, which concerns its form, not its contents. It is quite obvious that, *if* a scientific system is to be simple, comprehensive, and built up with discrimination, the presentation of this system will have to offer corresponding qualities. It must be brief; it must be well ordered; it must be expressed in precise, well chosen words; above all it will be *clear.*

Boileau said, "ce que l'on conçoit bien s'enonce clairement." The reverse is also true. If an idea can not be clearly worded, there is ground to fear that it is badly conceived. The fact that a scientific statement is expressed clearly is the test showing that the statement is sound in regard to reason and is properly discriminated.

A fine example, in this respect, is set by Descartes himself in his "Geometrie," a treatise which, just in a few pages, lays the foundations of analytical geometry. Another beautiful example is found in Pascal's dissertations on hydrodynamics, which have often been described as being as many little gems. But I can not enter here into a survey of the *results* to which the Cartesian principles have led. My object was simply to show how these principles have been introduced into science and what they do mean.

They were, as we have seen, the natural outcome of the views held by the best French scientists of a time in which modern thought generally, and French thought particularly, began to develop on new and most promising lines. Descartes had a clear conception of the

type of science which was wanted in his age. However, the promise then given of a sound rational science, as opposed to a purely logical or merely empirical science, was not actually made good until a much more recent date. If we except pure mathematics, or rather some parts of pure mathematics, the system of science on which we rely today was not actually framed, in its present shape, before the end of the eighteenth century. Then it was that the older sciences, like analysis, physics, chemistry, were placed upon really strong foundations, while biology and all the new sciences were just emerging from the chaotic state. The nineteenth century has justly been described as the century of science. It is therefore of special interest for the student of French civilization to see how France has played her part during that most remarkable period.

* * *

It was shortly before 1800 that, after a period of comparative stagnation, a new revival of scientific thought became apparent in France. Curiously enough this revival took place at a time which does not seem at all favorable—in the midst of the French revolution and the Napoleonic campaign. This is a strange coincidence. But we must remember that the French scientist of Descartes' class is not bound to be an indoor scholar or a white-bearded doctor. For him, there is no contradiction between learning and life. Rather would he believe that active life is an inducement to scientific work, that the great expenditure of energy which comes from danger is likely to give an impetus to science itself. So did it happen that the period about the year 1800 was one of great scientific production, and the very men to whom we owe that production have played a personal part in the great drama which was then shaking France and all Europe.

A few names will be sufficient, I think, to prove the correctness of this association.

Lazare Carnot, born in 1753, was one of the promoters of modern geometry. But, at the same time, he was an army officer and a statesman. He proved a most efficient minister of war. He was one of the first to discover Napoleon's ability and himself deserved the title of "organisateur de le victoire."

Another member of the Carnot family, Sadi Carnot, one of the founders of thermodynamics, was also an army officer engaged in active service.

Gaspard Monge was a great inventor in geometry. But he took an active part in the Revolution, was a state minister and a member of Napoleon's expedition to Egypt. Other members of the same expedition were Geoffroy-Saint-Hilaire, a well known biologist, and Berthollet, famous in chemistry.

Fourier, a promoter of mathematical physics, lived a most threat-

ened life throughout the Revolution. Lavoisier, who is considered by many as the chief founder of modern chemistry, held various posts in the Revolutionary administration, and was finally sentenced by a Revolutionary court and put to death.

Poncelet, a most original geometer, was an officer in Napoleon's army and made his greatest discoveries when a prisoner in Russia.

Arago, a great astronomer born in 1786, was also a strenuous man of action. Just when the war was raging between England and France, he was engaged in the measurement of a geodesic arc in Spain and North Africa. He was taken prisoner a number of times but always managed to escape under the most perilous circumstances.

Such were the French scholars of the beginning of the last century.

But quieter times have come, and the scientist of the Carnot type is now a figure of the past. Occasionally, to be sure, the tradition of 1800 has been renewed. Not to speak of a recent prime minister, there are a number of scientists who have played an active part in French public affairs. Conspicuous among them was Berthelot, one of the founders of organic chemistry, who not only was a senator and statesman, but took personal interest in nearly all fields of knowledge and action.

Berthelot's case is however an exception. Scientific work nowadays, when of the original and creative kind, requires so much time, so much application and concentration, that it can not be easily associated with outside activities. The reverse, however, is not true. It is quite feasible and most useful for a man engaged in active life to be thoroughly trained in science. In this respect, at least, France has preserved the tradition of 120 years ago. To promote scientific thought among men of action, the great inventors of that time had opened a new school, the *Ecole Polytechnique.* Up to the present day, this school has played an important part in the life of the country; through this institution and others, the best French engineers, officers, administrators, are given a scientific training of high standard and many of them thus develop a turn of mind in which we easily recognize the Cartesian spirit: clearness, preciseness, a rigorous method. The scientific ability, the directness of mind of the French artillery officers has often been praised during the war. It is largely due to the training and tradition of the *Ecole Polytechnique.*

But let us turn to the genuine research work done in France and see what remarks may be offered about it.

Coming to this point, I confess that I feel somewhat puzzled. The pure scientist of modern times is not in the least a striking figure. He is a simple man, living a simple life in his study or his laboratory. Many would even suspect him of being some kind of fossil with no passion, no feeling, no human weakness. Of course, this suspicion is

not correct. A man who does creative work is bound to have passions, but not of the sort that break out in every day life. Let us try, however, to discover, under the monotonous surface of his existence some characteristic features of the man.

I have already mentioned the fact that the French tradition, as defined by Descartes, is strongly opposed to the spirit of the old schools of specialists. The modern French student, to be sure, is mostly obliged to specialize. This has become necessary if one wants to do useful work. But the French student rather regrets this restriction on his activity, and he has none of the specialist's tastes or manners.

A natural consequence of the specializing habit is the way in which followers of the same line (the same *Fach*, as the Germans would say) are wont to associate together and live a distinct life. In so doing modern specialists are quite in keeping with the old custom. The old universities were precisely such associations of learned men who conversed and discussed among themselves without any regard for the opinions of the lay people outside. Their one aim was to gain authority and influence over their own kind. And the ambition of every young scholar in former times was to become a professor, a magistrate in his turn, and to be surrounded by a crowd of docile followers.

The scheme is not altogether a bad one. Anyone, I think, who has studied in one of the older German universities must admit that *there*, at least, some of the traditions of the past have been preserved with great advantages to all concerned. In the quiet city of Göttingen, among the woods and hills of the Hanover province, famous professors, a few years ago, still lived the same learned, methodic life which their predecessors had led. They worked in close association with their students. They ate and drank with them. They guided them step by step. And they used to share with them their intimate thoughts, their hopes, the difficulties which they met in their own researches; thus occasionally getting valuable assistance from the same young men whom they helped to get a start in academic life. The deep humility of many a student in such surroundings, his complete submission to his master, were rather surprising to the foreigner; but it can not be denied that the cooperation which such a submission made possible was followed in many cases by remarkable results.

In France, however, the ways of scientists and the conditions of university life are of a different type.

Like Descartes, the French student of science is mostly a man with an independent turn of mind. There lies his strength as well as his weakness. Working alone, and avoiding too frequent contact with his fellow-workers, he may thus have a better chance to discover really new and unexplored ways. He is less exposed to the danger of having his vision obscured by tradition, by opinions or prejudices of other

men, by the natural inclination to imitate. But, on the other hand, there are some kinds of work in which a single-handed man, whatever be his own resources, is not likely to succeed, in which some sort of cooperation is highly desirable. This is specially true of laboratory work, where a long series of delicate experiments is required. In this respect many Frenchmen will frankly admit that they have often been somewhat deficient. In organized scientific work, in teamwork, France is not as successful as she might have been. However, it should not be forgotten that, so far, the most original, the deepest discoveries have not been obtained by teamwork. And it is not unusual that one single man, in a small, inconvenient laboratory, lacking all modern conveniences, will make a striking discovery. Such was the case of Pasteur forty years ago. Such has been the case of the Curies.

To the individualistic turn of mind of the French man of science is probably due the fact that the intercourse between teachers and pupils is not in French universities what it is in a place like Göttingen.

We have seen that Fermat, Descartes and Pascal were not university men. Even at the present day, the French scientist, although he usually teaches in some university, is not exactly the man whom most people would call a professor. He does not associate with his students as closely as the typical teacher does. Henri Poincaré, for instance, was often described as being peculiarly closed and inscrutable to the many who came to study under him. He utterly disliked to speak about his own work while it was going on. He believed that absolute concentration was necessary to bring forth original thought and that academic intercourse, during the period of invention, could not but spoil the process. This view, it will be noticed, is in perfect agreement with the Cartesian principles. According to the French notion science is by no means the result of addition, of accumulation of knowledge and research. It is an accomplishment of reason, an act of direct intuition, which can not be divided and can not be made easier by combining the brains of several people.

It would be, however, quite a mistake to believe that French professors don't care to have frequent and friendly intercourse with their students. Henri Poincaré was much interested in beginners. But he did not try to impress his ideas upon them. He was rather anxious to get out of them the ideas which they might be forming in secret.

French students, like those of some other countries, are rather fond of criticizing. They have not too much respect for their teachers and sometimes follow their leadership chiefly by taking opposed views. Now you will find that the French professor, as a rule, does not try to check that tendency. He knows that there is an exaggeration in it, which will wear out with youth; but he thinks, as Descartes did, that a young, vigorous, not too scholarly mind, even if it has not yet hoarded

a big amount of knowledge, is apt to fall upon new and original ideas which a more experienced man might overlook. He believes in the power of fresh minds, not hampered by erudition, and he does his best to stimulate such minds.

The conditions which I have described so far as prevailing in modern France relate chiefly to creative work and invention. Invention, however, is only one part, the most important one, of scientific activity. Another part is the presentation and explanation of the facts and ideas, the making of a system or theory.

What shall we call, in science, a *theory?* This point we touched already when we were discussing Cartesian science. But it is only in recent years that the meaning and purport of constructive theories have been distinctly recognized; and French scientists and philosophers have helped much to clarify the question.

The French idea is—let us repeat it once more—that it is less important to collect data than to make a pertinent choice between them and to order and handle them according to clear principles, well reasoned out. From this it follows that the French scientist is bound to pay special attention to the requirements and to the merits of theories.

In what respect may we say that a scientific theory is contingent? To what extent is the theory a thing of our own making, the result of our own discrimination? To what extent, on the other hand, is it imposed upon us from the outside by an external necessity? Such were the problems which several French thinkers have discussed at length from the point of view of modern science.

The conclusion reached was quite in keeping with Descartes' view, namely, that the best science is the one which is most convenient and simple. Many different systems of science would be equally correct (for instance non-Euclidean geometry is just as true as Euclidean geometry). But only the science which is simple will be commendable.

It is not for me to discuss these views from the standpoint of philosophy. The metaphysical questions which they call forth may be debatable. But the scientific conclusions and precepts which men like Henri Poincaré cultivate have often been described as a scientific form of pragmatism. This is partly, but only partly true. To describe that position correctly we have to bear in mind that the Cartesian conceptions are still dominant in France. We are trying to mould science so as to make it simple. Now what does the word "simple" mean here? Is it exactly the same thing as *convenient?* Descartes' answer to this question is based on principles which don't satisfy us today. Yet his leading idea has survived; namely, that simplicity in science does not mean primarily practical convenience, but rather means being simple in regard to *reason*, in regard to Cartesian *good sense*. The constant

aim and preoccupation of the French scientist, when he makes up a theory, will be to take reason for his guide.

But if we put the matter so, one may ask, how then shall we define that faculty of reason on which we cause all science to rest? This question the modern scientist will not answer. It is beyond him. He is not as bold as Descartes and does not venture to describe reason. But he firmly believes that he knows quite distinctly, quite definitely, what a theory is to be like if it is built in accordance with the precepts of that undefined faculty of reason.

Take, for instance, the modern theories of physics as they grow in the hands of such great scientists as Hertz, Maxwell, Oliver Lodge, and see what becomes of the same theories when they are accommodated to French taste by Henri Poincaré, Duhem, Langevin or Perrin. You will recognize at once that the said theories are distinctly modified when they cross the borders of the different countries—which shows that there is really such a thing as a national ideal in scientific construction.

A striking feature in the books of many great English scientists of recent date is the constant appeal which they choose to make to material illustration, to concrete images and comparisons. Open an English treatise of electricity, Pierre Duhem used to say. You will be surprised to find there constant talking about strings, ropes, wheels, pulleys, waterfalls and so on. It seems, indeed, that such comparisons and interpretation are a distinct help to the English mind. It would not be quite so with the French mind. The French would think that this repeated resorting to imagination is rather likely to obscure the deep meaning of the theory.

Let us take, now, some German treatise of the first rank on the same subject. There we find a predilection for abstract, logical, well deduced constructions and mathematical reckoning. No material illustration of the facts, no attempt, even, to justify the long work except when it comes to be concluded. The peruser of the treatise is expected to be a disciplined, docile sort of man who will take the trouble of going through the whole, of devoting himself to hard reading without knowing beforehand where he is taken to and why he is asked to go that way. Science, so conducted, is chiefly a formal system. It may finally lead to practical applications, but, all along the way, you don't know whether it will; and the useful construction does not differ in form and character from any other which would be useless.

The French point of view in such matters is somewhat different. It is neither the English nor the German standpoint just described. The leading feature, in the presentation of a theory of physics in France is neither concrete interpretation nor pure deduction and computation.

Few images, to avoid dispersion of the mind, and a logical apparatus as reduced as possible, to avoid obscuration of the ideas by the

formal elements of deduction. The ideas themselves as clear, as obvious, as approachable to common sense as they can be. Such will be for the French the ideal theory.

* * *

I have tried to define, in the preceding pages, the features which seem to be most apparent in the personality, the work and the achievements of French men of science. To close this article, I confess that I have no definite conclusion to offer; nor would it be safe to synthetise any more an account which is already too schematic. In fact, real conditions can not possibly be as simple as one might infer from this account. The tendencies which I have tried to point out are often more potential than actual and only half—if at all—conscious. The exceptions, also, are numerous, so that any synthetic picture, like the one I have had in view, can never be more than partly true. But should the picture, for this reason, be dismissed as illusory and devoid of any practical value? I don't think so. When there is so much talk about exchanging professors, students, ideas, between distant nations, I believe that it may be worthwhile to emphasize, even with some exaggeration, the traits that are most likely to affect a would-be visitor to a country. This may help to avoid misunderstandings. If science of the type which I have described is to your liking, then go to France and you will probably come across some good representatives of such a science. If it disagrees with you, then stay at home and be indulgent.

ORIGIN OF THE ELECTRICAL FLUID THEORIES

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IN a previous paper an attempt was made to show how the hypothesis of an electric effluvium or an electric atmosphere, by means of which electrified bodies were supposed to exert an attraction or repulsion upon each other, played a prominent part in electrical theory for more than 150 years. In the meantime two kinds of electrification had been discovered, and this discovery greatly increased the difficulty of finding a satisfactory explanation of the phenomena of attraction and repulsion.

The discovery of electric induction by Stephen Gray was referred to in the previous paper. This discovery, along with many other important electrical discoveries, was made in 1729. In 1733, du Fay, a French officer and engineer, who had been repeating Gray's experiments, communicated to the Royal Society through the Duke of Richmond the first announcement of the discovery of two kinds of electrification, or, as he believed, two kinds of electricity. This letter was read before the Royal Society and is published in volume 38 of the Philosophical Transactions. In it du Fay describes a number of new electrical discoveries which he had made, some of them very important, as, for example, the fact that all solids when suitably insulated may be electrified by friction or contact with other bodies. Then he says:

> Chance has thrown in my way another Principle, more universal and remarkable than the preceding one, and which casts a new Light on the Subject of Electricity. This Principle is, that there are two distinct Electricities, very different from one another; one of which I call *vitreous Electricity,* and the other *resinous Electricity.* The first is that of Glass, Rock-Crystal, Precious Stones, Hair of Animals, Wool and many other Bodies; The second is that of Amber, Copal, Gum-Lack, Silk, Thread, Paper, and a vast Number of other Substances. The Characteristick of these two Electricities is, that a Body of *vitreous Electricity,* for Example, repels all such as are of the same Electricity; and on the contrary attracts all those of the *resinous Electricity*; so that the Tube made electrical, will repel Glass, Crystal, Hair of Animals, &c. when rendered electrick and will attract Silk, Thread, Paper, &c. though rendered electrical likewise. Amber, on the contrary will attract electrick Glass, and other Substances of the same Class and will repel Gum-Lac, Copal, Silk Thread, &c.
>
> Two Silk Ribbons when rendered electrical will repel each other; Two Woollen Threads will do the like, but a Woollen Thread and a Silk Thread will mutually attract one another.

Du Fay justly regarded this newly discovered fact regarding electrification as capable of explaining many electrical phenomena which up to that time had been incapable of explanation. He does not propose any hypothesis as to the mechanism of attraction or repulsion, nor does he propose any theory as to the coexistence of the two kinds of electricity in the same body or have anything to say about their neutralizing each other when combined in suitable proportions. This part of the two-fluid theory seems to have been proposed by Robert Symmer about 25 years later.

In 1745 a great impetus was given to the study of electrical phenomena by the discovery of the shock which may be produced by the discharge of an electrical condenser through the body. This discovery was first made by Dean von Kleist of the Cathedral of Camin in Pomerania. Dean von Kleist found that he apparently could lead a larger quantity of electricity down a nail into a flask containing mercury or alcohol when he held the flask in his hand than when it stood on a table. In trying to remove the nail from the flask after he had, as he supposed, filled it with electricity, he received a shock. He described this experiment and his sensations on receiving the shock in letters to several scientists in Berlin, Halle and elsewhere. These men failed to verify the experiment, perhaps on account of the poor insulating quality of the glass used, and none of them seemed to attach much importance to the announcement of Father von Kleist.

Within three months a similar discovery was accidentally made in the laboratory of Peter van Musschenbroeck in Leyden. Van Musschenbroeck was one of the leading scientific men of his day and his discoveries were widely published. He communicated his discovery in a letter to Réaumur, in Paris, and it was published in the Mémoires of the Académie in 1746.

The letter to Réaumur was written in January, 1746, and the account of the discovery which it contained is given below as translated in Benjamin's "Intellectual Rise of Electricity."

> I wish to inform you of a new but terrible experiment, which I advise you on no account personally to attempt. I am engaged in a research to determine the strength of Electricity. With this object I had suspended by two blue silk threads, a gun barrel, which received electricity by communication from a glass globe which was turned rapidly on its axis by one operator, while another pressed his hand against it. From the opposite end of the gun barrel hung a brass wire, the end of which entered a glass jar, which was partly full of water. This jar I held in my right hand, while with my left I attempted to draw sparks from the gun barrel. Suddenly I received in my right hand a shock of such violence that my whole body was shaken as by a lightning stroke. The vessel, though of glass, was not broken, nor was the hand displaced by the commotion; but the arm and body were affected in a manner more terrible than I can express. In a word, I believed that I was done for.

This "new and terrible experiment" of van Musschenbroeck's was widely published, and was repeated by scientific men all over Europe, in many cases before large audiences. It is doubtful if any scientific experiment ever created a more profound interest with the public to whom it was demonstrated than did the shock from van Musschenbroeck's electrified vial, and nothing ever seemed a greater mystery than it did until Franklin proposed the explanation which is still accepted. The apparatus by which the shock was produced came to be called generally the Leyden phial or Leyden jar; but in Germany, out of consideration for Dean von Kleist's discovery, it is called the *Kleistschen Flasche.*

Soon after the announcement of van Musschenbroeck's discovery, Benjamin Franklin, of Philadelphia, was presented with a tube of flint glass and was told of some of the wonders of electricity and the properties of the mysterious flask by his friend, Peter Collinson; and he at once began the series of electrical experiments, the results of which have profoundly modified all electrical theories from that time until the present, and which seem destined to determine to a large degree the electrical theories of the future.

Franklin's original discoveries were not more numerous than those of Stephen Gray, though he discovered the effect of points in collecting or discharging electricity, proved the identity of atmospheric and frictional electricity, discovered that bodies within a charged hollow conductor will take no charge from the inner surface of the charged conductor and explained the phenomena of the mysterious flask of von Kleist and van Musschenbroeck; but Franklin proposed a physical interpretation of the phenomena of electricity which received almost universal acceptance at the time, and which now, since several other theories have been tried and have proved unsatisfactory, seems destined again to become the fundamental theory.

It may be interesting to know that the theory of a single electric fluid as the cause of both kinds of electrification discovered by du Fay was proposed almost simultaneously by Franklin in Philadelphia and by William Watson in London, and from virtually the same experiment. Franklin announced his theory in a letter to Peter Collinson, dated June 1, 1747. After speaking of two men insulated on cakes of wax and electrifying themselves, one from rubbing a glass tube and the other from holding his knuckles near to the rubbed tube, while a third man stands on the floor near them, he says:

> These appearances we attempt to account for thus: We suppose, as aforesaid, that electrical fire is a common element, of which every one of the three persons above mention has his equal share before any operation is begun with the tube. A, who stands on wax and rubs the tube, collects the electrical fire from himself into the glass; and his communication with the common stock being cut off by the wax, his body is not again immediately

supplied. B, (who stands on wax likewise) passing his knuckle along near the tube, receives the fire which was collected by the glass from A; and his communication with the common stock being likewise cut off, he retains the additional quantity received. To C, standing on the floor, both appear to be electrified: for he having only the middle quantity of electrical fire, receives a spark upon approaching B, who has an over quantity; but gives one to A, who has an under quantity. If A and B approach to touch each other, the spark is stronger, because the difference between them is greater: after such touch there is no spark between either of them and C, because the electrical fire in all is reduced to the original quantity.

It may not be without interest to compare this concise explanation with the much more labored one proposed by Watson for the same phenomenon. Watson refers to an observation that had been made that a man standing on wax and holding his hand on a rotating glass globe could take no appreciable charge so long as the globe was insulated and held at a distance from other conductors, but would become charged if a conductor or another person, either insulated or uninsulated, should draw off the charge from the glass.

Watson's discussion of this experiment is given in Volume 45 of the *Philosophical Transactions of the Royal Society*, and is, in part as follows:

1. That what we call Electricity is the Effect of a very subtil and elastic Fluid, diffused throughout all Bodies in Contact with the terraqueous Globe (those Substances hitherto termed Electrics *per se* probably excepted), and everywhere, in its natural State of the same Degree of Density.

2. That this Fluid manifests itself only, when Bodies capable of receiving more thereof than their natural Quantity are properly disposed for that Purpose; and that then, by certain known Operations, its Effects shew themselves by attracting and repelling light Substances, by a snapping Noise, Sparks of Fire &c. directed towards other Bodies, having only their natural Quantity, or, at least, a Quantity less than those Bodies from which the Snappings, &c. proceed.

3. That no Snapping is observed in bringing any two Bodies near each other, in which the Electricity is of the same Density, but only in those Bodies in which the Density of the Fluid is unequal.

4. That this snapping is greater or less, in proportion to the different Densities of the Electricity in Bodies brought near each other, and by which Snapping each of them becomes of the same Standard.

5. That Glass, and other Bodies which we call Electrics *per se*, have the Property of taking this Fluid from one Body, and conveying it to another, and that in a Quantity sufficient to be obvious to all our Senses.

6. That in the Experiment in question, the Reason why no Snapping is observed by a Person upon the Floor touching him who rubs the Globe with his hands standing on Wax, without at the same time some other Non-electric supported by Originally Electrics, or otherwise being in contact with the Globe, is owing to whatever Part of this Man's natural Quantity of Electricity, taken from himself by the Globe in Motion, being restored to him again by the Globe in its Revolutions; there not being any other Non-electric near enough to communicate the Electricity to; and therefore, in this Situation, the Electricity of the Man suffers no diminution of its Density.

7. That the fact is otherwise, when everything else being as before, either a Gun-barrel suspended in Silk Lines, or a Man supported by Wax, or such like, is placed near the Globe in Motion; because then, whatever part of the Electricity of the Person rubbing is taken from him, is communicated either to the other Man or the Gun-barrel, these, from their Situation, being the first Non-electrics, to which Electricity taken from the Person can be communicated.

8. That under these Circumstances, as much Electricity as is taken from the Person rubbing is given to the other; by which means the Electricity of the first Man is more rare than it naturally was, and that of the last Man more dense.

9. That the Electricity in either of these Persons is in a very different State of Density from what it naturally was, or from that of any Person standing upon the Earth; this last being in a middle State between the two other Persons; that is, he has not his Electricity so rare as the Man rubbing the Globe, nor so dense as that of him supported by Electrics *per se,* and touching the Equator of the Globe.

10. That therefore the same Effect, a Snapping, is observed upon bringing any Non-electric near either of these Persons, from very different Causes: For it is apprehended, that, by bringing the Non-electric near him, whose Electricity is more rare, this Snapping restores to him what he had lost; and that by bringing it near him, whose Electricity is more dense, it takes of his Surcharge, by which means their original Quantity is restored to each.

Watson then refers to the explanation of the same phenomenon by Franklin, with which he had been made acquainted after the presentation of his paper to the Royal Society. Thus he says:

At this time I am tne more particular concerning the Solution of this singular Appearance as Mr. *Collinson,* a worthy member of this Society, has received a Paper concerning Electricity from an ingenious Gentleman, Mr. *Franklin,* a Friend of his in *Pennsylvania.* This Paper, dated June 1, 1747, I very lately perused, by Favour of our most worthy *President.* Among other curious Remarks, there is a like Solution of this Fact; for though this Gentleman's Experiment was made with a Tube instead of a Globe, the Difference is in no-ways material. As this Experiment was made, and the Solution thereof given upon the other Side of the *Atlantic Ocean* before this gentleman could possibly be acquainted with our having observed the same Fact here, and as he seems very conversant in this part of Natural Philosophy, I take the Liberty of laying before you his own Words.

Then follows Franklin's explanation of the experiment as we have already quoted it.

Franklin's theory of the relation of electricity to material bodies is more fully given in a letter to Peter Collinson under date of July 29, 1750, the year of the publication of Watson's paper. He says:

1) The electrical matter consists of particles extremely subtile, since it can permeate common matter, even the densest metals, with such ease and freedom as not to receive any perceptible resistance.

2) If any one should doubt whether the electrical matter passes through the substance of bodies, or only over or along their surfaces, a shock from an electrified large glass jar, taken through his own body, will probably convince him.

3) Electrical matter differs from common matter in this, that the parts of the latter mutually attract, those of the former mutually repel each other. Hence the appearing divergency in a stream of electrified effluvia.

4) But though the particles of electrical matter do repel each other, they are strongly attracted by all other matter.

Franklin introduced the use of the algebraic signs + and — to indicate the electrical conditions which Watson referred to as denser or rarer electrical states. Thus a body which contained a greater amount of the electrical fluid than it would contain if in electrical contact with the earth was said by Franklin to have a + charge, and one which contained less of the fluid than it would naturally take from the earth was said to have a — charge. From this point of view, the body with a + charge would give electricity to the earth and a body with a — charge would take electricity from the earth if put into electrical contact with it.

Cavendish used the term "pressure" to indicate the same idea. He regarded the electrical fluid in all bodies as under an external pressure and as always flowing in the direction of least pressure. A body with a + charge would then be one in which the electrical fluid was under greater pressure than in the earth, and a body with a — charge as one whose electrical fluid was under a less pressure than the earth's electrical fluid. If the electrical fluid is regarded as compressible, as it must have been by Watson, the + condition would indicate both an increased pressure and an increased density.

All of these concepts assumed an electrified earth, and, as was shown in the previous paper, it was upon the assumption of an electrified earth that Cavendish, and probably Aepinus, undertook to prove the absence of an electrical atmosphere about charged bodies.

The concept of an electrically neutral earth seems to be due to Robert Symmer, in England. In 1759, during Franklin's residence in England, Symmer borrowed some electrical apparatus from him and repeated some of his experiments. As a result of these experiments, he came to a different opinion as to the nature of electrification from the one proposed by Franklin but failed to convert Franklin to his point of view.

In Volume 51 of the *Philosophical Transactions* is a group of four papers by Symmer in which he gives his reasons for believing in two electrical fluids. Of the two principal arguments which he proposes, one is derived from the sensation experienced when the two coatings of a weakly charged Leyden jar are touched by the fingers of one hand. In this case, Symmer says the sensation is that of a shock, or blow, upon the fingers touching both coatings of the jar, with no distinction to indicate that the electricity strikes from one coating rather than from the other.

The other argument is based upon the fuzzy appearance on both sides of a card or of several sheets of paper of the perforation made by a single electric spark, "indicating that the electric fluid has either entered or left both sides," and upon the effect of a spark discharge through a number of sheets of paper with a sheet of tin-foil between them. In this case the tin-foil may not be perforated and the holes made by the spark on opposite sides of the tin-foil may not meet opposite the same point in the foil. In this case there is a little dent in the tin-foil opposite both perforations, indicating that the tin-foil has been struck from opposite sides in the two cases.

After referring to the apparent difficulty of explaining these phenomena by a single electric fluid, Symmer sums up his case as follows:

> On the other hand, it is my opinion that there are two electrical fluids (or emanations of two distinct electrical powers) essentially different from each other; that electricity does not consist in the efflux and afflux of those fluids, but in the accumulation of the one or the other in the body electrified; or, in other words, it consists in the possession of a larger portion of the one or of the other power, than is requisite to maintain an even balance within the body; and, lastly, that according as the one or the other power prevails, the body is electrified in one or in another manner.

It will be seen that Symmer has added to du Fay's notion of two electricities the assumption that all bodies in their natural state possess both kinds but in such quantities that their individual effects are neutralized.

It is interesting to know that Franklin was ignorant of du Fay's discovery when he proposed his theory of a single electric fluid. Later, his friend, Mr. Kinnersly, of Boston, who had taken part in some of Franklin's work, made the discovery that the electricity induced by the friction of the hand on a sulphur globe would discharge the electricity induced in the same way on a glass globe. Thus, if he charged a Leyden jar by sparks from a rubbed glass globe and then allowed a rubbed sulphur globe to spark into it, he found that the jar was first discharged and then, if the sparking were kept up, became charged again. He also found that the jar remained discharged if the glass globe and the sulphur globe were allowed to spark into it at the same time. This caused him to inquire of Franklin whether the glass, or the sulphur, acquired a + charge when rubbed.

Franklin concluded for several reasons, the most important of which seems to have been the different character of the brush discharge of the two, that glass took the excess charge from the body rubbing it, while sulphur gave off electricity to the rubber. Thus, the brush discharge from a positively electrified body is longer and more diverging than from a negatively electrified body. Franklin also observed that the "electric wind" given off from a point is stronger from a body electrified from glass than one electrified from sulphur. He concluded for

these reasons that the electric fluid was escaping from the charged glass and was being collected by the charged sulphur.

Franklin did not attach much importance to his attempted identification of the + and — electric conditions. Priestley says that one question which greatly puzzled Franklin was why negatively electrified bodies should repel each other, since his theory was that particles of electric fluid repel each other while the particles of material bodies attract each other. It would seem from these hypotheses that two bodies containing a deficiency of the electric fluid should attract each other.

The opinion that the electric fluid is attracted by the particles of material bodies led to the modification of Franklin's theory by the introduction of the assumption that the particles of material bodies, when free from electricity, must also repel each other. In making this assumption, an important discovery made by Stephen Gray was seemingly overlooked, and though this observation has been repeated thousands of times it seems still to be overlooked by most writers on electrical theory. Gray found that a hollow box of wood when charged seemed to take as great a charge as a solid block of the same size, and every student of electricity now knows that a hollow conductor, no matter how thin its walls, has the same electric capacity as a solid conductor of the same shape and size. If the particles of the electric fluid were attracted by the particles of the conductor, this would not be the case.

The Franklinian theory, even when modified by the assumption of a repulsion between the atoms of material bodies still differed in important respects from the two fluid theory of du Fay and Symmer, since in the latter theory in its final form an electric discharge always consisted in the passage of both kinds of electricity in opposite directions between the two conductors. This theory as it was developed prior to 1767 is described by Priestley, in his "History of Electricity," as follows:

> To show my absolute impartiality, I shall, notwithstanding the preference I have given to Dr. Franklin's theory, endeavor to represent this to as much advantage as possible, and to do it more justice than has yet been done to it, even by Mr. Symmer himself; who, as I observed before, has fallen into some mistakes in his application of it. Indeed, hitherto very little pains has been taken with this theory, nor has it been extended to any great variety of phenomena.
>
> Let us suppose then, that there are two electric fluids, which have a strong chymical affinity with each other, at the same time that the particles of each are as strongly repulsive of one another. Let us suppose these two fluids, in some measure, equally attracted by all bodies, and existing in intimate union in their pores, and while they continue this union to exhibit no mark of their existence. Let us suppose that the friction of any electric produces a separation of these two fluids, causing (in the usual method of electrifying) the vitreous electricity of the rubber to be conveyed to the conductor, and the resinous electricity of the conductor to be conveyed to the rubber. The rubber will then have a double share of the resinous electricity, and the conductor a double share of the vitreous; so that, upon this hypothesis, no substance

whatever can have a greater or less quantity of electric fluid at different times; the quality of it only can be changed.

The two electric fluids, being thus separated, will begin to show their respective powers, and their eagerness to rush into reunion with one another. With whichsoever of these fluids a number of bodies are charged, they will repel one another, they will be attracted by all bodies which have a less share of that particular fluid with which they are loaded, but will be much more strongly attracted by bodies which are wholly destitute of it, and loaded with the other. In this case they will rush together with great violence.

Upon this theory, every electric spark consists of both the fluids rushing contrary ways, and making a double current. When, for instance, I present my finger to a conductor loaded with vitreous electricity, I discharge it of part of the vitreous, and return as much of the resinous, which is supplied to my body from the earth. Thus both the bodies are unelectrified, the balance of the two powers being perfectly restored.

When I present the Leyden phial to be charged, and, consequently, connect the coating of one of its sides with the rubber, and that of the other with the conductor, the vitreous electricity of that side which is connected with the conductor is transmitted to that which is connected with the rubber, which returns an equal quantity of its resinous electricity; so that all the vitreous electricity is conveyed to one of the sides and all the resinous to the other. These two fluids, being thus separated, attract one another very strongly through the thin substance of the intervening glass, and rush together with great violence, whenever an opportunity is presented, by means of proper conductors. Sometimes they will force a passage through the substance of the glass itself; and, in the meantime, their mutual attraction is stronger than any force that can be applied to draw away either of the fluids separately.

Thus it is seen that the two fluid theory involves more assumptions than does the theory of a single fluid. In the two fluid theory the notion of combined, or neutralized, electricities seems to be necessary to account for some of the commonest phenomena of electrification. Maxwell speaks of this necessity as follows:

The introduction of the two fluids permits us to consider the negative electrification of A and the positive electrification of B as the effect of *any one* of three different processes which would lead to the same result. We have already supposed it produced by the transfer of P units of positive electricity from A to B, together with the transfer of N units of negative electricity from B to A. But if $P+N$ units of positive electricity had been transferred from A to B, or if $P+N$ units of negative electricity had been transferred from B to A, the resulting "free electricity" on A and B would have been the same as before, but the quantity of "combined electricity" in A would have been less in the second case and greater in the third than it was in the first.

It would appear therefore, according to this theory, that it is possible to alter not only the amount of free electricity in a body, but the amount of combined electricity. But no phenomena have ever been observed in electrified bodies which can be traced to the varying amount of their combined electricities. Hence either the combined electricities have no observable properties or the amount of the combined electricities is incapable of variation. The first of these alternatives presents no difficulty to the mere mathematician, who attributes no properties to the fluids except those of attraction and repulsion, for he conceives the two fluids simply to annul one another, like $+e$ and $-e$, and their combination to be a true mathematical zero. But to those who cannot use the word fluid without thinking of a substance it is difficult to conceive how the combination of the two fluids can have no properties at all, so that the addition of more or less of the combination to a body shall not in any way affect it, either by increasing its mass or its weight, or altering some of its other properties. Hence it has been supposed by some, that in every process of electrification exactly equal quantities of the two fluids are transferred in opposite directions, so that the total quantity of the two fluids in any body taken together remains always the same. By this new

law they 'contrive to save appearances,' forgetting that there would have been no need of the law except to reconcile the "Two Fluids" theory with facts, and to prevent it from predicting non-existent phenomena.

In the one fluid theory as stated by Maxwell the notion of saturation takes the place of neutralization. Thus Maxwell says:

> If the quantity of electric fluid in a body is such that a particle of the fluid outside the body is as much repelled by the electric fluid in the body as it is attracted by the matter of the body, the body is said to be saturated. If the quantity of fluid in the body is greater than that required for saturation, the excess is called the Redundant fluid and the body is said to be Overcharged. If it is less, the body is said to be Undercharged, and the quantity of fluid which would be required to saturate it is sometimes called the Deficient fluid.

The Franklinian theory as modified by the addition of the hypothesis that the particles of ordinary matter, as well as the particles of the electric fluid, must be self repellent lasted well into the 19th Century. Its replacement by the two fluid theory seems finally to have been due to its assumption of an electric attraction between the particles of the electric fluid and the particles of material bodies.

Thus Dr. Thomas Thomson, in his *Outline Of The Sciences of Heat And Electricity*, published in 1830 and just before the important work of Faraday, says:

> The second datum, that the electric fluid is attracted by matter with a force inversely as the square of the distance, is also inconsistent with the electrical phenomena. For the quantity of electricity accumulated in bodies is always proportional to the extent of their surface, and not to the quantity of matter in them, as would be the case if any attraction or affinity existed between them. All substances, whatever their nature may be, are capable of receiving the same quantity of electricity, provided the extent of their surfaces be equal. And, finally, it has been shown that electricity accumulates only on the surfaces of bodies, and that nothing but the pressure of the ambient atmosphere prevents it from making its escape.

This objection to the single fluid theory seems valid, but it should also apply equally well to the theory of two fluids when an attraction is assumed between either, or both, the fluids and the particles of material bodies. That is, this objection is not more fatal to a theory of a single fluid than to one of two fluids, and cannot be looked upon as deciding between them. This fact seems to have been implicitly recognized by the physicists of that day, since it came to be assumed as a part of the accepted theory of the day that no attraction or affinity exists between either of the electric fluids and material bodies.

But if this be assumed, how may an electrified body attract an unelectrified body? Or how may two oppositely electrified bodies attract each other? This question is asked and answered by Dr. Thomson as follows:

> But if there be no affinity or attraction between electricity and matter, it may appear, at first sight, difficult to account for the fact that when bodies are excited, that is, contain a super-abundance of electricity, they *attract* or *repel* each other with forces varying inversely as the square of the distance; bodies having the same kind of electricity repelling, and those having different

kinds attracting each other. But this apparent difficulty admits of a very simple explanation.

If we suppose two excited and insulated spheres placed at a small distance from each other, it is obvious that the only forces which can occasion the motion of the bodies, are the mutual attraction or repulsion of the fluid in the one, to the fluid in the other. For the repulsions exercised by the particles of fluid in each body on one another, can have no effect in producing a motion in the center of gravity of either body. If the two spheres consist of non-conducting matter, the unknown power which gives them the non-conducting property, will prevent the escape of the electricity from each. Therefore the mutual attractions and repulsions of the fluids, as they cannot escape from the matter, may be supposed to carry the matter along with them, and thus to cause the globes to approach or recede, according as they are charged with different kinds of electricity, or with the same kind.

When an excited conducting body is insulated the superinduced electricity forms a coating on its surface, and (if we suppose the body spherical) the thickness of this coating will be everywhere the same. This electricity presses upon the ambient air, which prevents it from making its escape. The excited sphere, in consequence of this action of the electricity, which is proportional to the square of its thickness, will be less pressed upon by the surrounding atmosphere, than if it were not excited. But as the pressure, though diminished, is everywhere equal, there will be no tendency of the sphere to move from its place. Let us suppose the conducting sphere to be charged with positive electricity, and let us conceive a mass of sealing wax or gum lac, charged negatively, to approach it, a portion of the combined electricity natural to the sphere, will be decomposed. The positive portion will accumulate on the surface of the sphere next the mass of sealing wax, being attracted by its negative electricity. The superabundant positive electricity already in the sphere will accumulate at the same surface for the same reason. While the decomposed negative electricity will accumulate at the opposite surface of the sphere, being repelled by the negative electricity of the sealing wax. Thus the coating of electricity next the sealing wax will become thicker than before, while the coating at the greatest distance will become thinner. Hence the electricity in the part of the sphere next the sealing wax will press more upon the air than before, while the air will press more than before upon that surface of the sphere which is farthest from the sealing wax. Both of these pressures have a tendency to cause the sphere to move towards the sealing wax, and if the weight of the sphere be sufficiently small it will move accordingly.

It seems impossible that any one with even a smattering of mechanics could take the above explanation seriously, much less accept it as "a very simple explanation," but Dr. Thomson evidently took it seriously, and he proceeded immediately after the above quotation to put it into mathematical form. And Dr. Thomson was a very eminent scientific man, professor of chemistry in Glasgow, fellow of the Royal Societies of London and Edinburgh and member of most of the learned societies of England and the Continent. It accordingly is probable that this represents the best explanation at that time available of this difficult electrical problem.

De La Rive, in his great treatise on Electricity published twenty-three years later, is still wrestling with this problem. He still seemed satisfied with the explanation which Thomson had given with regard to insulators, that while their particles could have no attraction for electricity, still "The unknown power which gives them the non-conducting property will prevent the escape of electricity from each," and accordingly that they may be pulled together by the attraction of their

electric fluids; but in the meantime Becquerel, Sir W. Snow Harris, and others, had repeated the discovery made one hundred years before by Hauksbee and Stephen Gray that electric attraction and repulsion may take place in the best air pump vacuum. De la Rive, referring to this experiment, says:

> Sir W. Snow Harris has observed that the attractions and repulsions between electrifed bodies take place in vacuo as they do in air; a further proof of the error we should commit by admitting the atmospheric pressure to play a part in the phenomena. This fact, on the other hand, is very well explained by admitting that the electricities are retained, in the portions of the surfaces where they are distributed, by the insulating effect of the film of air that remains adjacent, and in no degree by atmospheric pressure: once retained at the surface by this cause, as they would have been by a coating of varnish, they are no longer able to obey their mutual attraction or repulsion, except by drawing with them the bodies themselves, if their mass is not too great. This explanation, even though it should not be based upon observations made in vacuo, would seem to us in every case preferable to that in which atmospheric pressure is made to intervene; this intervention being implicitly founded on a purely hypothetical idea, namely, that electricity is a fluid of the same kind, and about the same tenuity as air and gases.
>
> Further, while still believing that the electric effects observed in vacuo, as well as others no less curious, of which we shall speak hereafter, are due to the film of air that remains adhering to the surface of bodies, we by no means wish to pretend that conducting bodies have not for themselves the property of preserving, or rather *coercing* on their surface a certain dose of electricity, feeble, it is true, but nevertheless sensible.

At the time of writing of de la Rive's treatise the interest in statical electrical phenomena was declining, owing to Volta's discovery of the electric current at the end of the 18th century and the brilliant discoveries of Davy and Faraday in electrochemistry and of Oersted, Ampère and Faraday in electromagnetic induction. The question as to how two oppositely electrified bodies may attract each other while there is no attraction between the particles of the electric fluid and material particles was overlooked for the time being. Then the electric theory of Faraday was at this time coming to the front in English speaking countries, and from the point of view of this theory this question could have no significance, since no electric fluid of any kind was assumed in the Faraday theory.

Since the discovery and isolation of the electric fluid by J. J. Thomson and his followers at the close of the 19th century, the question as to what part this fluid takes in the attraction or repulsion of electrified bodies has assumed its earlier importance, but the electrical theory of the present time is not concerned with the physical interpretation of phenomena, but only with the mathematical statement of their quantitative relations, and all qualitative relations are being ignored. The problem of the nature of electric attraction accordingly remains in the hopeless condition in which it was left by de la Rive.

THE MIOCENE SHORE-FISHES OF CALIFORNIA

By Dr. DAVID STARR JORDAN
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RECENT studies of the fossil fishes in the Miocene deposits about Los Angeles and at Lompoc in Southern California, have enabled us to distinguish about sixty-five species of bony fishes, besides a dozen or more species of sharks. Most of the latter are from the shales of Kern County, north of the Tahachapi range. With the exception of two extinct types (*Hemipristis* and the so-called *Wodnika*) the genera are all still represented on the coast. The present paper deals with true fishes only and these belonging to a period roughly estimated as two million years ago.

The study of these fishes of California shows certain facts very clearly.

1. The present fauna of California is derived from it, with a certain admixture from the north and from Japan. In the Miocene fauna so far as known there are no types characteristic of Japan.

2. The Miocene fauna is a transitional one, having its roots in the Eocene or Cretaceous. But of neither of these periods have representatives been found in Pacific Coast deposits either in America or Asia.

3. The Tertiary fauna of California is nearly all included in families still extant on the coast. All of the species are distinct from their living allies, and most of them must be placed in different genera.

4. The Miocene fauna is plainly ancestral to the present one.

5. The most striking difference which appears is that thus far we have found no trace among the fossils, of the *viviparous* surf-fish (*Embiotocidae*) which form so conspicuous a part in the existing fauna of

THYRSOCLES VELOX (JORDAN AND GILBERT) RESTORED

THYRSOCLES VELOX (JORDAN AND GILBERT) LOMPOC
A Mackerel, Allied to the Spanish Mackerel, Scomberomorus Maculatus (Mitchill).

California, and which should abound in just the conditions in which fossils have been preserved. As two genera (*Ditrema Neoditrema*) of this family, representing different sections, are found in Japan, it is possible that the California surf-fishes are of Asiatic origin and have crossed to California in relatively recent times. Among the fossil fishes actually known we find none which suggests any affinity with Asiatic forms. Most of them are distinctly characteristic of California, a few only belonging to types now wanting in California but found in the Gulf of Mexico and in one or two cases in the Mediterranean.

Besides the surf fishes there are some other forms rare or missing which one might have expected to find. Gobies are very scarce although species are now abundant in all shallow waters along the coast. Sculpins (*Cottidae*) now extremely abundant along the coast are wanting. As the Okhotsk region is their center of distribution, they may be late comers in California. There are no sardines, anchovies, or true herring, the extremely numerous herring-like forms being all of extinct genera. We find no blennies, which is also an unexpected fact, as numerous species frequent just such small bays as then occurred in the Archipelago about Los Angeles. There are also no Labroid fishes, forms which now abound in the kelp banks outside the bays.

6. No species either distinctly tropical or distinctly subarctic appear among these Tertiary fishes. We must therefore conclude that the Miocene temperature differed little from that which obtains at present.

7. It is evident from the absence in the deposits containing fishes, of silt or other rain-washed material, that the climate was arid. In the Lompoc deposits of pure diatoms there is no sedimentary material whatever.

8. The localities in which fossil fishes have been found are of two categories:

ZORORHOMBUS VELIGER, JORDAN, (RESTORED)
A flounder allied to the European brill. Bothus rhombus, L.

(a) Shallow inlets within a group of small islands scattered about in the region now comprised in the counties of Los Angeles and Orange. The deposits in these little bays are mixed diatoms and fine clay, and the individuals are all either of species of small size or else the young of larger forms. In a few places individuals are found in clay or in fairly hard sandstone, more rarely in pure diatoms. It is a curious fact that the species found about Los Angeles are with the possible exception of two small fishes (*Lygisma, Quaesita*) all different from those taken in the diatom beds at Lompoc.

(b) The deposits of pure diatoms, unmixed with sand or clay, and rarely showing other organisms. Here are found multitudes of fishes, a few birds (petrels, gannets and wading birds) and an occasional porpoise. We found no crustaceans and no echinoderms. There are a few annelids, in one place a small clay bank burrowed full of holes by *Pholadided* or some similar mollusk, and in another place a single shell of some species of *Arca.* With the diatoms are occasional microscopic rhizopods and spicules of sponges.

The Lompoc deposit fills what was once a small narrow-mouthed or bottle-shaped inlet, on the north side of the Sierra Santa Ynez, the backbone of Santa Barbara County. Since these mountains rose from the sea, this little bay of Lompoc became filled with diatoms in in-

credible numbers to the depth of 1,400 feet. A little stream having eroded one side and large cuttings having been made for commercial purposes, we may now see a section of the whole mass from top to bottom. I have elsewhere[1] shown that a species of herring (*Xyne grex*) had at one time gathered in such numbers as to cover the whole floor of the bay to the exclusion of all other kinds of fish. This was at a level of 950 feet above the sandstone and shales on which the all diatom deposits rest. Among these millions on millions of herring young specimens are not found, all the individuals ranging from 6 inches to 8 inches in length, and not a foot in the whole four square miles so far as yet exposed has less than eight or ten of these fishes. In one single place all by themselves there is a deposit of young herring two or three inches long.

Dr. Edward C. Franklin figures on data which I have furnished that there must have been some 1,200 millions of these herring and that the number of diatoms in the whole bay might be represented by the unit 1 followed by at least 30 ciphers.

Among the herring we find no other kinds of fish whatever, and the question of what caused the sudden death of this vast multitude and the sudden burial in clouds of white diatoms constitutes a problem very difficult to solve. The only clews to the solution have been offered by Dr. Albert Mann, who suggests that the great crowding, whatever its cause, may have raised the temperature of the water, a matter to which

ZORORHOMBUS VELIGER, JORDAN, LOMPOC

1 "A Miocene Catastrophe" *Natural History,* American Museum, New York, xx, p. 18, 1920.

herring are peculiarly sensitive. The bulk of the other fishes found are predatory forms which have come to this bay in search of the herring. Two specimens of a large mackerel have herrings in their stomachs. These various forms I have described in two papers written in collaboration with Dr. Gilbert of Los Angeles. These are "Fossil fishes of Southern California" (David Starr Jordan and James Zaccheus Gilbert), Stanford University Publication, University series, 1919 (Sept. 6) and "Fossil fishes of diatom beds of Lompoc" (Jordan and Gilbert), l. c., 1920 (February).

No fossil fish is ever quite complete—one part or another is wanting. Ordinarily the head is the least satisfactory part. While the bones of the skeleton are picked clean by small organisms in the sea, the soft mass of the brain decays and in rotting it disintegrates the bones which lie around it. Although in most fishes the bones of the head are especially firm and hard, they are very seldom preserved in fossil forms and the student of bony fishes is obliged to give his attention to the skeleton and to the neural and haemal structures which spring from it. The position of the fins can be made out from these bones, but the rays are usually broken. Hence, however determined, there are always elements of doubt as to the accuracy and completeness of any restoration.

No traces of sharks are found in the diatom deposits although multitudes of sharks' teeth are found in the rocks which in other regions overlie the deposits of diatom. As each living diatom contains a minute droplet of oil, it is thought that the great oil deposits of Southern California may come from these masses of diatoms, and it is thus evident that the abundance of sharks' teeth may be an indication of oil. This is especially true in Kern County, where sharks' teeth exist in enormous abundance. It is possible that the oil escapes to the air in regions where, as in Lompoc, the diatom deposits are exposed; but where they are covered by later layers of sand and shale, the oil has been preserved to our own time.

A CALIFORNIA ELK DRIVE

By Dr. C. HART MERRIAM
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CALIFORNIA enjoys the distinction of having within its borders a number of animals and plants that do not inhabit other parts of the United States. Among these are several giants—the redwood of the coast and the bigtree or giant sequoia of the Sierra; the great California condor whose spread of wing equals if it does not exceed that of the condor of the Andes; and several species of grizzly bears culminating in the huge *Ursus magister* of the Cuyamaca and Santa Ana Mountains, now believed to be extinct.

Another interesting animal peculiar to the state, though by no means a giant among its kind, is the valley elk (*Cervus nannodes*), a species now confined to the south end of the San Joaquin plain but formerly abundant throughout the Great Interior Valley. Within the memory of men now living, large bands of these elk inhabited the tule marshes and sloughs of Tulare, Buena Vista, and Kern Lakes, and those bordering the San Joaquin and Sacramento Rivers, but a couple of decades ago the handful of survivors had drifted south to the southern border of the Tulare plain and had there made their last stand. The exact locality is the neighborhood of Buena Vista Lake, on what is known as Buttonwillow Ranch—one of the vast cattle ranches of the Miller and Lux Company.

Here they had a measure of protection but proved costly wards, making light of the high enclosing fences and playing havoc with the alfalfa and other crops. In the spring of 1904, Miller and Lux offered, through the Biological Survey of the Department of Agriculture, to present the herd to the Government. The offer was accepted, it being agreed that the ranch owners should corral the animals. But what to do with them was a serious question. However, a location was finally selected, on Middle Fork Kaweah River within the boundaries of the Sequoia National Park, where, through the courtesy of the Department of the Interior, I was permitted to establish and fence an elk park.

Miller and Lux had previously built a corral for shipping cattle; it was on the railroad 4 miles west of Buttonwillow at a place called Lokern. The plan was to drive the elk into this corral, which had been strengthened for the purpose and had been extended by the addition of long arms reaching far out on the plain.

The country is desert, comprising broad stretches of bare alkaline clayey and sandy soil, dotted at intevals with dull desert brush—a hot arid uninviting region, bounded on the south and west by the barren treeless foothills of the Templor and San Emidio Mountains—a region strikingly unlike that inhabited by the elk of the Rocky Mountains and Pacific Coast.

There were, we were told, three bands of elk: the main band numbering about 100; another of about 40; and an independent group of five very old bulls. The main herd, composed of cows, calves, two-year-olds, and a few adult bulls, had been for some time in the habit of feeding nightly in an alfalfa field a few miles southwest of Buttonwillow; the next largest band ranged a little farther west; while the small group of very old bulls could usually be found not far away.

The plan was to drive the main band from their nightly feeding ground to the corral, a distance of 6½ miles. The date had been set for November 12, 1904, and riders of neighboring ranches had been invited to take part. About 35—all expert vaqueros and cattle-ropers—had volunteered. Some went out the night before and camped along the route of the proposed drive, but the main body set out from Buttonwillow in the very early morning—long before daylight—in order to get behind the elk, between them and the foothills, while it was still dark.

The affair was in charge of the superintendent of the ranch, James Ogden, who went with the vaqueros to personally direct the drive.

THE LEADER OF THE HERD

They rode quietly to the far side of the alfalfa field in which the Elk were feeding and waited for them to come out. The place is where the level Joaquin plain ends, giving way to the barren foothills of the San Emidio and Templor ranges that stretch away to the south and west. The riders were expected to prevent the elk from entering the hills and to drive them slowly to the corral.

I did not take part in the drive, but accompanied by my then assistant E. W. Nelson (now chief of the Biological Survey), went direct to the corral and waited. We had arranged to photograph the incoming elk, and were also charged with the duty of keeping the onlookers from crowding forward and frightening the approaching animals. While waiting, we saw from time to time moving patches of dust; they appeared in various directions, all heading toward the corral, and were caused by persons from distant ranches riding in to witness the drive. Some came on horseback, some in buggies, some in heavy ranch wagons.

Suddenly, far away to the southeast, a very different cloud appeared; it was a broad low sheet of dust moving steadily westward, obviously coming nearer. Instantly all eyes were strained. One man climbed the water tank, from which point of vantage he called out that he could distinctly see elk in the front of the moving dust. Our spirits rose; all was excitement at the corral. Then the dust vanished—almost as suddenly as it had appeared—and we saw it no more.

In the course of an hour a rider arrived with the depressing news that the elk had broken for the hills and could not be turned; they had charged the line of oncoming vaqueros, had pushed on between the horsemen and escaped to the hills. A few had been pursued, roped, and 'hog-tied', and a horseman had been sent to the ranch for wagons to bring them in.

After a long wait the first wagon arrived, drawn by six horses. On its broad platform were three elk, flat on their sides, each with all four legs lashed together. There was an old bull with large antlers, battered and broken from much fighting, a two-year-old bull with long spike-horns, and a calf about two thirds grown. They had been injured in the beginning, in the roping and violent fighting before they were thrown and tied, and during subsequent struggles had beaten their heads against the hard floor boards of the dead-ax wagon. The calf was already dead; the others were nearly paralyzed from lying so long in one position in the hot sun.

The wagon was driven into the corral, where the two live elk were seized, carried, and dragged into one of the enclosures. Then the ropes binding their feet were loosed and the gates closed.

The animals had great difficulty in getting up and still more in

ARRIVING AT THE CORRAL, "HOG-TIED"

standing after they were up, and were some time in recovering the use of their legs.

Nevertheless, the old bull did things that amazed the onlookers. When roped he had fought so furiously that the skill and agility of the vaquero were taxed to the utmost to save himself and his horse from a bloody death. And when in the corral, no sooner were the ropes cut than the bull charged with such earnestness—in spite of the fact that he was unable to stand still on his feet—that the men were obliged to escape over the fence with the utmost promptness. He was 'game' from the start, and never for an instant relaxed his determination to fight every animate thing within reach. Discovering the spike-horn bull, whose fetters had been loosed simultaneously with his own, leaning against the corral fence near by, he instantly lowered his head and charged, driving his strongly curved brow-tines into the side of the younger animal, which soon began to bleed at the mouth and nose, and later died. The old bull, although for some time unable to walk, or even to stand erect without leaning against the corral, was nevertheless able to make sudden rushes at those who were bold enough to enter the enclosure or to sit on the nearby fence. To prevent further harm he was again roped and stretched, and his horns were sawed off close to his head. This was intended to break his spirit and render him easy to manage, but as subsequent events proved, it had no such effect.

Shortly after noon the second wagon was seen approaching. It had been obliged to travel a long distance over the dry hills to pick up the widely scattered elk, of which it brought five—an old cow, a two-year-

SAWING OFF HIS HORNS IN THE CORRAL

old bull, a cow calf, and two bull calves. Three of these were already dead, only the cow and one of the bull calves reaching the corral alive. This made 8 elk at the corral, 4 alive and 4 dead.[1] Of the 4 living, it will be remembered that one—the spike-horn buck—had already received a mortal wound. The cow, calf, and wounded spike-horn were moved from the corral compartments to the middle passage and thence through the narrow chute into a cattle car, which had been brought for the purpose. This was accomplished without serious difficulty. But with the old bull the case was very different. He stubbornly refused to be either led or driven, and in spite of his hornless condition and the weakness of his legs, no one could be found who was willing to enter his compartment to argue with him at close quarters. His aggressive attitude continued and his face wore an expression of defiant rage. When any one approached, he dilated his nostrils, gritted his teeth, and uttered a low expiratory snort—the only noise he ever made.

Volunteers were called for, but no one responded. A hundred men, including the best riders and boldest vaqueros of the Joaquin, were gathered at the fence, but no one pressed forward to try his mettle with the hornless bull. Then Ogden, the superintendent, turning to his head vaquero, Billy Woodruff, asked if he was afraid to go in and get that elk out. Woodruff replied that if he could ride his horse in he would

1 The skins and skulls of the elk that died during the drive were preserved and sent to the Biological Survey and are now in the U. S. National Museum. They proved to be a new species, which because of its relatively small size I named *Cervus nannodes*.—Proc. Biological Soc. Washington, Vol. 18, pp. 24-25, Feb. 2, 1905.

do it, whereupon he swung himself into the saddle and rode through the gate.

The scene that followed is not likely to be forgotten by any who witnessed it. Woodruff's horse was a magnificent animal—nearly black, large, broad-chested, powerful—experienced and daring in everything relating to the roping and handling of cattle. From first to last he and his rider moved as if impelled by a single purpose. There seemed to be no attempt to guide on the part of the man, and no attempt at independent action on the part of the horse—they were one, not two. The instant the horse entered the enclosure it was evident to everyone that he not only understood his master, but also that he thoroughly understood the business he was there for. He, as well as the onlookers, knew that he was there to get that elk out of the corral. But no sooner had he entered the gate than the bull, who by this time had regained the use of his legs, met him with a fierce charge, striking him full in the breast with the butts of his sawed-off horns. The horse received the shock without a tremor and took in the situation at a glance. As the elk backed for a second charge the horse sprang forward and crowded him back to prevent him from getting leeway for another rush. By force of greater weight the horse pressed his adversary to the fence and tried to push him out through the corral gate. But the elk stubbornly refused to go, and in spite of inferior size punished the horse so severely that it is a marvel he didn't break and run. The elk was an experienced, aggressive, and expert fighter; his strength, activity and quickness were amazing, and the way he rained fearful blows on that horse was painful to behold. By turning and slipping a little to one side he managed repeatedly to swing his head so as to strike the horse in the ribs and with the stubs of his horns to tear and fray the fenders and sweat leathers of the saddle. Once he hit the rider a glancing blow on the leg which nearly broke it. The horse tried hard to receive the attacks on his breast, and did so whenever possible, never for an instant relaxing his efforts to crowd the animal out of the corral; but the elk, taking advantage of the corners, could not be forced out.

Finally, realizing the hopelessness of further attempts at crowding, Woodruff and the horse tried a new dodge. They backed slowly out to and through the open gate. This gave the elk the opportunity he had all along sought of getting a running start for his blows, with nothing to intercept or lessen their force, and he availed himself of it to the utmost. For a distance of thirty or forty feet the brave horse backed slowly to the gate, receiving terrible punishment from the sledge-hammer-like blows, which he received full on the breast. In this way the old bull was slowly enticed to the open gateway, where, as if realizing the trick, he suddenly stopped. But it was too late. The gate

opened in, and at this moment several men who had been watching from the top of the fence, dropped down quickly behind the gate and by a united effort pushed it shut, thus crowding the elk out into the narrow middle passage, where the battle was immediately resumed. Here the absence of corners and angles in which the elk could gain a purchase soon told in favor of the horse, who, straining every muscle, forced his adversary into the narrowing chute that led to the car. But even now the elk had no thought of giving in. Once, by a tremendous effort, he rose up under the horse's breast and actually lifted the heavy animal off his fore feet. Then the horse, recovering, lowered his broad breast against the elk and by a swift and powerful rush pushed him backward through the narrow chute to the open door of the car. Here the elk, finding himself unable to stand against the force that was driving him backward, and unable to see where he was being carried, whirled and sprang into the car. The shout that burst from the throats of the onlookers was in appreciation of the achievement of Woodruff and his splendid mount; while a second shout voiced admiration for the undaunted valor of the poor old bull who, against such tremendous odds, had fought to the very last.

After all the elk had been brought in, the vaqueros and spectators, about a hundred in all, were treated by Ogden to a barbecue lunch. Half a beef and some elk meat had been roasted over coals in a long trench, a huge pot of coffee was boiled, and there was bread enough for all.

The vaqueros had many tales to tell of the events of the chase, the main facts of which appear to be: At early daybreak a small bunch of bull elk with antlers came out of the alfalfa field, ran off to the westward and were not again seen. A little later the main band appeared. Their numbers were variously estimated at from 85 to 105. They consisted mainly of cows, calves, and two-year-old males with spike-horns. There were only two, or at most three, adult males with branching antlers. The herd set out in a northwesterly direction along an old channel of Kern River, going toward the corral. The riders were behind, between them and the Templor foothills. The elk moved off on an easy trot—a pace that made it necessary for the horses to strike a lively gait to keep up. For two or three miles the elk held their course toward the corral and the riders began to think it would be an easy matter to drive them in. Then suddenly, and without apparent cause, the band turned abruptly to the left and made for the hills. This brought them face to face with the riders, who had kept a parallel course. The men shouted, threw up their arms, and bore down upon the rapidly approaching elk, but the elk paid absolutely no attention to them and continued their course to the hills. When the two forces met, the elk passed between the horses, some so close that the horsemen

TAKING ELK TO THE PARK, NOVEMBER, 1914

were obliged to get out of the way to escape injury—for the bulls with horns were exceedingly dangerous and could not be closely approached without risking the lives of the horses. But most of the animals were females and young.

Finding it impossible to drive the elk, several of the vaqueros yielded to temptation, gave chase to an individual animal, overtook it, kept it alongside for some distance, crowding it with the horse, hitting it repeatedly with the riata, or even in some cases kicking it, in a futile effort to turn it back, and finally, in sheer desperation, roping it. The two adult bulls with branching antlers, two spike bucks, a cow and several calves were lassooed, thrown, "hog-tied"—the front and hind legs lashed firmly together—and left on the ground to be picked up later by the wagons. One of the old bulls was so far away that the wagons did not reach him at all, and later a horseman was sent to liberate him. The other—the first one roped—was the terrible fighter already mentioned at the corral. He was believed to be the leader of the band and obviously had earned the distinction. From first to last he had shown no fear and had fought every living thing within reach.

The car containing the four elk was taken to Exeter, whence the animals had to be hauled by wagon 35 miles to the park. The wounded spike-horn and the old cow had died, leaving only the old bull and the calf.

In anticipation of the moving, three huge and very strong wagon-crates had been built, each to be hauled by a six mule team. Each crate was divided into six compartments, separated by gates that could be lifted up between solid uprights; and the rear end also had been made a sliding gate.

When the car containing the elk arrived at Exeter, one of the wagons was backed up against it and so placed that the elk could step directly from the car into the cage. The calf did this promptly, but the old bull declined to enter. While in transit he had fought and butted and kicked until he had splintered several of the side boards of the car. A half barrel of water that had been put into the car stood in the doorway. By means of a pole it was upset and pushed to one side. No sooner had this been done than the elk, seeing it in a new position, charged and dealt it a resounding blow that sent it rolling over the floor. This evidently pleased him, for arching his back and leaping forward he struck it again and again, making a great noise, and followed it around the car, butting it furiously as if it were the cause of all his trouble.

Finally, after repeated efforts to drive him out had failed, a rope operated by long poles was slipped over his neck, he was dragged through the open door into the crate and the two rear gates were closed behind him. This enraged him still more and he attacked the crate with vigor, butting furiously in one spot until the boards began to give way. Meanwhile the men on top of the crate succeeded in forcing down the gates immediately in front and behind him, so that he was confined in a narrow cell only two feet in width. Finding that he could no longer butt, having no room to swing his head, he at once began to kick and kept on kicking, dealing the boards behind him a series of rapid sledge-hammer blows until it was evident that they would soon be reduced

CALF ELK AFTER ARRIVING AT THE ELK PARK

to splinters. When he had kicked as long as he could with one foot, he would change and kick with the other. The force and rapidity of the blows were astonishing; it seemed incredible that his strength could hold out so long.

When the wagon reached Lemon Cove (a distance of 12 miles) the constant kicking had so demoralized the crate that it had to be taken to a blacksmith shop for repairs. An old ranch gate was secured and roped on the outside, and the crate was further strengthened by additional iron bolts. When Three Rivers was reached at 9 in the evening, still other repairs were necessary, and a halt was made for the night. In the morning the driver, who had laid his bed close to the wagon, announced that the elk had kicked all night, never resting more than five minutes at a time.

After again repairing the crate we set out for the park, still 12 miles distant. Arriving at the enclosure, the wagon was driven through the gate and turned around, facing the entrance; the horses were taken out, and holes were dug for the hind wheels in order to let the wagon bed down to the level of the ground. Then the rear gates were lifted, giving the calf his liberty. He was not at all afraid and at once ate grass from my hand. But he did not like the looks of the bull and soon climbed a nearby hill. Then the other gates were raised, giving the bull an opportunity to step out. For the first time since his capture he did what was wanted; he voluntarily crept to the rear of the wagon and hobbled out on the ground. Looking around for an enemy to attack and not seeing any—some of the men having stationed themselves outside the park fence, the others on top of the crate—he set out for the river, only a few rods away. His courage had not forsaken him, but his strength had; he was no longer the proud aggressive wild beast he had been. He had reached his limit. The terrible ordeal he had been through: the struggle incident to his capture; the rough hot ride to the corral, hog-tied, on the hard floor of the dead-ax wagon; the outbursts of passion in the corral; the fighting and second roping in connection with the sawing off of his horns; the battle with the big horse; the ceaseless violence of his destructive assaults first in the car, then in the crate, continued for three days and nights, had finally undermined even his iron frame, so when at last he found himself free on the ground he presented a truly pitiful picture. With his head bent to one side and back curved, with one ear up and the other down, and with a dejected helpless expression on his face, he hobbled wearily away, barely able to step without falling. Slowly he made his way to the river, waded in, drank, crossed to the far side, staggered laboriously up the low bank, and lay down. The next day he was found in the same spot—dead.

Profiting by the failure to drive the elk into the corral in 1904, Mr.

Ogden in the following year adopted a wholly different plan, which proved far more successful. Instead of attempting to *drive* the animals he organized *a chase* by experienced vaqueros, the object being to rope the individual elk. The chase took place a few miles from Buttonwillow on October 15, 1905. Nearly 30 were roped. Of these, 3 died before shipment; 25 were shipped, and 20 reached the park alive, forming a splendid nucleus for a growing herd.

The wild elk remaining on the Buttonwillow ranch multiplied steadily, and their depredations on alfalfa and Egyptian corn were correspondingly severe. In 1914 the Miller & Lux Company decided to attempt the capture of a very large number and invited the California Academy of Sciences to take charge of their distribution. The offer was accepted, and Dr. B. W. Evermann, director of the Academy's activities, arranged for the shipment of the elk to municipal parks and other available tracts in different parts of California.

A new method was inaugurated by the superintendent, Mr. Ogden. A huge corral a quarter of a mile long was built in an alfalfa field to which the elk came every night to feed. Here on the night of October 11, 1914, 150 came into the corral and were enclosed, but the next day 90 escaped. Three days later about 25 more were captured. During the latter part of the month 54 were distributed to different localities in the state.

Again, in 1915, the same corral was used in the same way, resulting in the capture of more than 100 elk, of which 92 were distributed. At that time it was estimated by Dr. Evermann that the number still remaining in Kern County was between 350 and 400.

THE PROGRESS OF SCIENCE

THE SECOND INTERNATIONAL CONGRESS OF EUGENICS

In this journal special attention has always been given to problems of evolution, heredity and eugenics. As older readers of the THE POPULAR SCIENCE MONTHLY will remember, it gave the first American publication to the work of Spencer, and, to a certain extent of Darwin, Huxley and the other leaders in the development of the doctrine of evolution. It was indeed under the elder Youmans a journal primarily devoted to the cause of evolution at a time when the word stood for heresy not only with the general public, but also among most men of science.

During the past twenty years under its present editorial control, THE SCIENTIFIC MONTHLY has continued to devote a considerable part of its space to work bearing on heredity and eugenics. Francis Galton printed here articles laying the foundation of eugenics, and the leading American students of genetics—Brooks, Wilson, Morgan, Conklin, Davenport, Jennings, Pearl and many others have communicated the results of their work to the wider scientific and educated public through this journal. In like manner, many articles by leaders in the subject have been printed on human heredity in so far as it is open to experimental or statistical study, and in other subjects on which a science of eugenics must rest—population, birth and death rates, immigration, racial differences, human behavior, etc.

We are consequently pleased to be able to record the holding in New York City of the second International Congress of Eugenics and to print in the present issue of the MONTHLY several of the more important addresses by foreign representatives. Shakespeare left no descendants, and Ben Jonson remarked that nature, having made her masterpiece, broke the mold. The four sons of Charles Darwin have followed scientific careers, a fine example of family heredity and tradition. It is a special privilege to welcome to the United States and to print the address in advocacy of eugenics of Major Leonard Darwin, based so largely on the works of his father, Charles Darwin, and of his cousin, Francis Galton. We hope to be able to publish in subsequent issues a general account of the congress by Dr. C. C. Little, the secretary, and several of the papers containing the results of more special scientific research. The program was strong in genetics, in which America now probably is leading. But all the divisions maintained good standards, the more doubtful theories and premature applications of ignorance, to which newer sciences such as eugenics and psychology are subject, having been in general avoided.

THE MEETING OF CHEMISTS IN NEW YORK CITY

The sixty-second meeting of the American Chemical Society, held like the Congress of Eugenics in New York during September, may lead to the hope that the city will give as much concern to becoming the center of the scientific as of the financial world. It was partly an Anglo-American meeting, for the Society of Chemical Industry having met in Canada, a number of the English and Canadian members took part in the New York meeting.

When the visiting guests crossed the border into the United States at Niagara Falls, President Harding welcomed them with the following telegram:

It is a pleasure to extend greetings

to the gathering of American, Canadian and British Societies representing the chemical sciences and industries meeting on American soil. Probably none of the materialistic sciences holds promise of so great contributions to human welfare in the coming generations as that which your organization represents. The developments of applied chemistry involve both a possibility of vastly increased horrors in human conflict and alternately inestimable benefits to a peaceful civilization. Let us hope that a science so fraught with either good or vicious possibilities may be turned, through the wisdom of the nations, to the benefit and advancement of mankind.

The meeting in New York was appropriately presided over by Dr. Edgar F. Smith, lately provost of the University of Pennsylvania and twenty-five years before president of the society. At the opening meeting at Columbia University, addresses were made by Francis P. Garvan on "Chemistry and the State," by Sir William Pope on "Chemical Warfare" and Professor R. F. Ruttan on "Organization of Industrial Research in Canada." At the closing general meeting Dr. Smith gave the presidential address on "Progress in Chemistry." This address was preceded by the unveiling of the Priestley portrait which is to be placed in the National Museum, the unveiling being accompanied by a description of the life and work of Priestley, by Dr. C. A. Browne.

An international meeting was held in the grand hall of the College of the City of New York after an organ recital by Professor Samuel A. Baldwin.

Chemistry and Civilization: Dr. Edgar F. Smith, provost emeritus, University of Pennsylvania, in the chair.

Science and Civilization; The Rôle of Chemistry: Dr. Chas. Baskerville, director of the laboratories, College of the City of New York; chairman, International Committee.

Energy; Its Sources and Future Possibilities: Dr. Arthur D. Little, chemical engineer and technologist, Boston.

The Engineer; Human and Superior Direction of Power: Dr. Leo H. Baekeland, honorary professor of chemical engineering, Columbia University.

Chemistry and Life: Sir William J. Pope, professor of chemistry, Cambridge University.

Theories: Dr. Willis R. Whitney, head of research department, General Electric Company.

Research Applied to the World's Work: Dr. C. E. K. Mees, head of research department, Eastman Kodak Company.

Problem of Diffusion and Its Bearing on Civilization: Professor Ernst Cohen, professor of chemistry, University of Utrecht.

Catalysis; The New Economic Factor: Professor Wilder D. Bancroft, professor of physical chemistry, Cornell University.

THE AMERICAN PUBLIC HEALTH ASSOCIATION

A third scientific meeting, like the Congress of Eugenics and the Chemical meeting concerned largely with the public welfare, will be held in New York City during the autumn. The fiftieth annual meeting of the American Public Health Association will be the occasion of a health fortnight from November 8-19. It is hoped that its slogan, "Health First," will stimulate interest throughout the country. Health fortnight will include three major divisions—a Health Institute from November 8-11; a Health Exposition, November 14-19; the Fiftieth Annual Meeting of the American Public Health Association, November 14-19.

The Public Health Exposition will be conducted under the joint auspices of the Department of Health of the City of New York and the American Public Health Association. Already allotments of space indicate that at least two entire floors of the Grand Central Palace will be occupied by the exhibitors. The exhibits will include those of educational and philanthropic organizations and those of commercial houses producing approved articles of health value. The

MAJOR DARWIN PROFESSOR OSBORN MRS. OSBORN
MEMRERS OF THE INTERNATIONAL CONGRESS OF EUGENICS

PROFESSOR MOERNS PROFESSOR SHULL DR. DAVENPORT
AT THE AMERICAN MUSEUM OF NATURAL HISTORY

profits from the sale of tickets, after the cost of the exposition and the convention are defrayed, will be devoted to establishing nutritional clinics for the benefit of undernourished children.

The Health Institute from November 8-11 will present to visitors an opportunity to see the operations of established methods applied to various phases of public health work. About forty demo strations have been planned.

Following the week of the institute and the observance of Health Sunday, will come the opening of the scientific sessions, the meetings of the American Public Health Association in celebration of its semi-centennal. The sessions will begin on November 14 and the headquarters will be at the Hotel Astor. The scope of the meetings is indicated by their division into the following: General Sessions, Public Health Administration, Child Hygiene, Public Health Publicity and Education, Laboratory Section, Vital Statistics Section, Industrial Hygiene Section, and Food and Drug Section.

SCIENTIFIC ITEMS

We record with regret the death of J. W. Richards, professor of metallurgy at Lehigh University; and of Dr. Arno Behr, the American industrial chemist; of G. W. Walker, the English seismologist; and of Henry Beaunis, known for his work on physiological psychology and hypnotism at Nancy and later at Paris.

Dr. C. S. Sherrington, professo. of physiology at Oxford University and president of the Royal Society, has been elected president of the British Association for the meeting to be held at Hull in 1922. It is expected that the meeting of 1923 will be at Liverpool and the meeting of 1924 at Toronto.

The University of Edinburgh has conferred the degree of doctor of laws on Dr. Irving Langmuir, of the research laboratory of the General Electric Company, Schenectady, who at the meeting of the British Association in that city opened the discussion on "The Structure of Molecules."

Dr. Alexis Carrel, of the Rockefeller Institute for Medical Research has been elected a national associate of the French Academy of Medicine, of whom there are only twenty.

The 1921 volume of the Summarized Proceedings of the American Association for the Advancement of Science, the publication of which has been delayed owing to the printers' strike, will soon be issued from the office of the permanent secretary of the association. The volume contains the old and the new constitution, the lists of officers, and references to *Science* for the reports of the Pacific Coast meeting (summer of 1915), the Columbus meeting (1916), the New York meeting (1917), the Pittsburgh meeting (1918), the Baltimore meeting (1919), the St. Louis meeting (1920), and the Chicago meeting (1921). It also contains the complete list of members of the association, corrected to June 15, 1921. Members who have already ordered the volume will be sent copies as soon as the book is published; those who have not ordered it may still do so, the price being two dollars, payable when the order is placed. The price to others is two dollars and fifty cents. The new list constitutes a directory containing the names, degrees, positions, addresses, etc., of about 12,000 scientific workers and others interested in scientific progress. It has been prepared from data obtained through special information blanks sent to all members.

THE SCIENTIFIC MONTHLY

DECEMBER, 1921

THE INBRED DESCENDANTS OF CHARLEMAGNE: A GLANCE AT THE SCIENTIFIC SIDE OF GENEALOGY

By Dr. DAVID STARR JORDAN

STANFORD UNIVERSITY

See the march of history
Strewn with cast-off finery,
And the way of common things
Cluttered with the pomp of kings.

THERE has lately been placed in my hands a great chart of American genealogy running back to the marriages of Isabel de Vermandois with two successive husbands—Robert de Bellomont, Earl of Leicester, and William, Second Earl of Warren and Surrey—and showing the lines of descent of some hundreds of well-known families from the beginning of the twelfth century, the reign of Henry I of England, down to the present time. This chart, the work of Miss Sarah Louise Kimball of Palo Alto, California, furnishes the text of the present essay. It embodies the results of long and patient research by its maker, supplemented by conclusions of many other experts in genealogy. But my present purpose is to consider only one scientific phase of the matter.

And first I may premise that to the biologist an ancestor is not primarily a forbear, but a carrier of inheritable potentialities. For men and women transmit to posterity not their actually developed traits, but rather their inborn tendencies, "the raw material out of which character is forged", a complex of potentialities. That is to say, heredity carries potentiality, not the completed results of education and environment. I shall, however, waive further discussion of the physiology or psychology of inheritance; I wish only to indicate some generalizations drawn (largely) from a study of Miss Kimball's chart.

Let us first note that notwithstanding its elaboration, its thousand or more ancestral names constitute merely a fragment, a scant shred in the great warp and woof of the genealogy of even a single person, or of the record of descendants of even a single pair.[1] For if the an-

[1] In this connection I remarked with interest that in the "Waldo Genealogy" (1902) by Waldo Lincoln of Worcester, Mass., the record of a single family for less than three hundred years, or eight generations, upwards

cestry of one individual running back to the twelfth century could be written out, using a square inch to each name, it would occupy something like a fourth of a square mile. A full chart of all the two hundred millions, more or less, of people of English ancestry scattered over the world would cover some twenty-five millions of square miles.

The simplest numerical calculation gives bewildering results. As each person has had two parents, four grandparents, eight great-grandparents, and so back endlessly in geometrical progression, every adult of today, allowing three generations to a century, would (if facts permitted) count not less than 134,192,256 separate ancestors in the year 1100. Furthermore as in the indicated progression with a ratio of two, the sum of the series is equivalent, minus one, to its highest term, each descendant should have 134,192,255 intervening forbears, making 268,384,511 in all. Again, each child of this generation has twice as many ancestors as either parent—that is 536,769,022 in all, of which incalculable number not one would have died in infancy or without issue. This computation, however, has led us to figures manifestly impossible in view of the fact that the total population of England in 1100 did not exceed two millions, and that probably not one-tenth of these, beset as they were by war and pestilence, left permanent descendants.

The simple explanation is, of course, that every ancient forbear must be counted over and over thousands of times in each individual case. Indeed, no one can guess how many tangled lines lead down to him from a single pair in the days of Henry I.

Conversely, if any one couple of the twelfth century and their successors left on an average four children, thus doubling the number three times to the century, their descendants alone, facts permitting, would count 134,192,256, as would the descendants of every other pair similarly fertile,—the whole making a nominal total far exceeding the present population of the globe! Thus, in this computation also, intervening individuals must be reckoned over and over again almost to infinity.

These conclusions as to the tangled lineage of the English people give a clue to the origin and persistence of racial traits in general; they are the stigmata of blood relationship. Moreover, as we have abundant evidence that the children of Warren and Isabel, like hundreds of other early notables, were descended from Alfred the Great and Charlemagne alike, it is not without reason that Miss Kimball calls the English people "the inbred descendants of Charlemagne".

of 19,000 persons are named as either descended from Cornelius Waldo and Hannah Cogswell—both of whom came from Berwick in Wiltshire, England, to Ipswich, Massachusetts, about 1640—or else married to one of their posterity; these many individuals were residents of 11,700 different towns in the United States. Besides Waldo, upwards of 3,000 other surnames appear, brought into the series by the marriage of Waldo women.

This fact now leads us to another important consideration; noble and peasant are really of one blood. For studies of American ancestry show clearly the effects of the law of primogeniture. The eldest sons of "good families" or of the nobility naturally developed into Royalists and Cavaliers; younger sons and daughters' sons, left without inheritance, became as easily Roundheads, Dissenters and Puritans. The legend on one of Cromwell's battle flags asked: "Why should the elder son have everything and we nothing?" To put it another way, why should "blue blood" be supposed to flow in the veins of the first born only?

Fortunately, those exposed to the deteriorating influences of ease and unearned power were few in number, a conspicuous minority. The others became part of the mass of commoners who have made England great. Samuel Johnson once cynically observed that primogeniture is an excellent thing, as "it ensures that there shall be but one fool in the family!" Happily it also provides that the high qualities which in other days set nobleman apart from peasant shall be spread through the whole body of the people by means of a constant transfusion from the "first estate" to the third. The lack of such a system left France, especially, a prey to the reaction inevitable in a people overrun by a hungry and impecunious nobility.

Miss Kimball's chart shows plainly the method by which the diffusion takes place. The daughter of a king, for example, marries a nobleman; one of her descendants takes a squire or younger son; a daughter of the squire marries a yeoman, whose children are accordingly of kingly descent. And every farmer of English lineage may boast of as much of the "germ plasm" of William, Alfred, or Charlemagne as any royal household in Europe; reversedly, plebeian blood may be mingled with the "bluest", usually to the betterment of both. As a matter of fact, indeed, very few Englishmen or Americans of English origin are without royal blood; nor is it likely that the coat of arms of any king living does not conceal the bar sinister of the peasant.

At the beginning of the twelfth century, as already stated, Isabel de Vermandois married successively Robert de Bellomont, Earl of Leicester, and William de Warren, Earl of Warren and Surrey. The charms or virtues of that far-off lady are not concerned in this discussion, any more than the manly qualities of either of the earls, though all three exalted personages were no doubt ancestors of yours, gentle reader, as well as of the present writer.

Isabel died on February 13, 1131. Her record comes down to us because of a very distinguished lineage, her ancestral line on both sides leading back through six separate strains to Charlemagne. She was the daughter of Prince Hugh the Great, Duke of France and Burgundy, leader in the First Crusade and father of Hugh Capet, King of

France; her mother, Adelheid de Vermandois, boasted blood equally blue, and her second husband was descended from Alfred.

By the Earl of Leicester, Isabel had two children—Robert and Elizabeth de Bellomont; by the Earl of Warren, two others—Gondred and Ada de Warren. Each of the four lines of descent then passes through a long series of English nobility, each allowing a younger son or daughter, or daughter's son to drop from time to time into the undistinguished ranks of the middle class or even into the common peasantry, while a few of the line of Elizabeth de Bellomont, though by no means the most eminent of their group, were set apart by laws of inheritance as occupants of royal thrones. Meanwhile, as I have implied, the elder sons, holding land and titles, remained in the Cavalier-Tory-Conservative caste, while their disinherited brothers and sisters became Dissenters, of whom many of the most obstinate or most enterprising sought freedom or fortune in the New World.

To illustrate these propositions I give below a series of ancestral records, each showing one of the many "direct lines" leading down from Isabel de Vermandois to Americans, well-known or otherwise.

GEORGE WASHINGTON

Let us begin with George Washington, a man of the highest personal character and unquestioned statesmanship, but socially rather a typical English country squire, though one of the wealthiest colonials of his day. The reasons which lay behind the emigration of Washington's ancestors to Virginia I shall not try to indicate, but apparently they did not seek fortune nor freedom of worship.

Robert de Bellomont, Earl of Leicester, m. Isabel de Vermandois
Elizabeth de Bellomont m. Gilbert de Clare, Earl of Pembroke
Richard de Clare, "Strongbow," Earl of Pembroke, m——
Isabel de Clare m. William le Maréchal, Earl of Pembroke
Eve de Maréchal m. William, Baron de Braose
Maude de Braose m. Roger, Baron Mortimer
Edmund, Baron Mortimer
Roger, Baron Mortimer
Edmund Mortimer
Roger Mortimer, Earl of March
Edmund Mortimer, Earl of March
Elizabeth Mortimer m. Sir Henry Percy, "Hotspur," Earl of Northumberland
Henry Percy, Earl of Northumberland
Margaret Percy m. Sir William Gascoigne
Elizabeth Gascoigne m. Gilbert de Talboys
Sir George de Talboys
Anne de Talboys m. Sir Edward Dymoke
Frances Dimoke m. Thomas Windebank
Mildred Windebank m. Robert Reade
Col. George Reade (Virginia, 1637)
Mildred Reade m. Col. Augustine Warner
Mildred Warner m. Lawrence Washington
Augustine Washington m. Mary Ball
GEORGE WASHINGTON

ABRAHAM LINCOLN

My next example presents certain marked contrasts. Beginning with the same aristocratic ancestry, the line of descent passes into Wales, then through a group of Welsh farmers, one of whom, doubtless to better his condition, came over to Pennsylvania, whence his pioneer descendants moved on to Virginia and westward. Out of this series rose one who became the most truly eminent statesman of his century. The career of Lincoln thus perfectly illustrates the possibilities of "noble" self-extrication among a people unburdened by the caste system of Europe.

Robert de Bellomont, Earl of Leicester, m. Isabel de Vermandois
Elizabeth de Bellomont m. Gilbert de Clare, Earl of Pembroke
Richard de Clare, "Strongbow," Earl of Pembroke
Isabel de Clare m. William le Maréchal, Earl of Pembroke
Eve de Maréchal m. William, Baron de Braose
Maude de Braose m. Roger, Baron Mortimer
Edmund, Baron Mortimer
Roger, Baron Mortimer
Maude Mortimer m. John, Lord Charleton
Jane de Charleton m. John, Baron Le Strange
Elizabeth Le Strange m. Gryffydd Wychan
Gryffydd Wychan
Lowry Wychan m. Robert Puleston
John Puleston
Margaret Puleston m. David ap Ievan ap Einion
Einion ap David
Griffith ap Llewellyn
Catherine Griffith m. Edward ap Evan
Lewis ap Griffith m. Ellen Edwards
Robert ap Lewis
Evan ap Robert
Evan ap Evan
Cadwallader Evans (Pennsylvania, 1700)
Sarah Evans m. John Hank
John Hank
Joseph Hank (Virginia about 1740) m. Nancy Shipley
Nancy Hanks m. Thomas Lincoln
ABRAHAM LINCOLN

GEORGE V

We have seen that the early English forbears of Washington and Lincoln are identical for two hundred years and more. It is interesting also to note that the ancestry of the present king of England (as well as that of the late Kaiser and most of the continenal princes now in exile or otherwise) derives from the same initial series.

Robert de Bellomont, Earl of Leicester, m. Isabel de Vermandois
Elizabeth de Bellomont m. Gilbert de Clare, Earl of Pembroke
Richard de Clare, "Strongbow," Earl of Pembroke
Isabel de Clare m. William le Maréchal, Earl of Pembroke

Eve de Maréchal m. William, Baron de Braose
Maude de Braose m. Roger, Baron Mortimer
Edmund, Baron Mortimer
Roger, Baron Mortimer
Edmund Mortimer
Roger Mortimer, Earl of March
Anne Mortimer m. Richard Plantagenet, Earl of Cambridge
Richard Plantagenet, Earl of York, m. Cecily Neville
Edward IV m. Elizabeth Woodbridge
Elizabeth Plantagenet m. Henry VII (Tudor)
Margaret Tudor m. James IV (Stuart) of Scotland
James V (Stuart)
Mary Stuart, Queen of Scots, m. Lord Darnley
James I (Stuart, James VI of Scotland)
Elizabeth Stuart m. Frederick V. of Bohemia
Sophia m. Ernest Augustus of Brunswick
George I. m. Sophia Dorothea
George II m. Wilhelmina Carolina of Brandenburg-Anspach
Frederick Louis, Prince of Wales
George III m. Charlotte Sophia of Mecklenburg-Strelitz
Edward, Duke of Kent, m. Victoria Mary Louise of Saxe-Coburg-Gotha
Victoria m. Albert of Saxe-Coburg-Gotha
Edward VII (Guelph) m. Alexandra of Denmark
George V

GROVER CLEVELAND

This "first citizen" of our land also belongs to the Bellomont-Vermandois line.

Robert de Bellomont, Earl of Leicester, m. Isabel de Vermandois
Elizabeth de Bellomont m. Gilbert de Clare, Earl of Pembroke
Robert de Bellomont, "the Consul," Earl of Gloucester
Mabel de Bellomont m. William de Redvers de Vernon, Earl of Devon
Mary de Redvers de Vernon m. Peter Prouz
William Prouz
Walter Prouz
William Prouz
Sir William Prouz
William Prouz
Alice Prouz m. Sir Roger Moelis
Alice Moelis m. John Wotton
Alice Wotton m. Sir John Chichester
Richard Chichester
Nicholas Chichester
John Chichester
Amias Chichester
Frances Chichester m. John Wyatt
Margaret Wyatt m. Matthew Allyn of Cambridge, Mass.
Mary Alleyn m. Capt. Benjamin Newberry
Rebecca Newberry m. Samuel Marshall
Abiel Marshall
Sarah Marshall m. James Hyde
Abiah Hyde m. Rev. Aaron Cleveland
William Cleveland m. Margaret Falley
Richard Falley Cleveland
Grover Cleveland

THEODORE ROOSEVELT

Two lines of descent from Isabel down to Roosevelt are on record, the one leading through a long series of Scottish worthies, the other by way of the Puritan forbears of Jonathan Edwards.

Robert de Bellomont, Earl of Leicester, m. Isabel de Vermandois
Elizabeth de Bellomont m. Gilbert de Clare, Earl of Pembroke
Richard de Clare, "Strongbow," Earl of Pembroke
Isabel de Clare m. William le Maréchal, Earl of Pembroke
Isabel Marshall m. Robert Bruce, Earl of Annandale
Robert Bruce, Earl of Warwick
Robert Bruce, King of Scotland
Marjory Bruce m. Walter, High "Steward" of the King
Robert II (Stuart), King of Scotland
Robert III, King of Scotland
Marjory Stewart m. Sir Duncan Campbell
Elizabeth Stuart m. Sir James Douglas
Sir James Douglas
Sir John Douglas
James Douglas
Arthur Douglas
John Douglas
James Douglas
John Douglas
Euphemia Douglas m. Dr. John Irvine (Georgia, 1765)
Anne Irvine m. Capt. James Bulloch
Major James Stephens Bulloch
Martha Bulloch m. Theodore Roosevelt (1)
THEODORE ROOSEVELT

ROBERT EDWARD LEE

I may next present one of the greatest of American generals, whose forbears throughout, so far as the present recorded line goes, were people of at least local distinction.

William de Warren, Earl of Warren and Surrey, m. Isabel de Vermandois
Mildred de Warren m. Roger de Bellomont de Newburgh, Earl of Warwick
Waleran de Newburgh, Earl of Warwick
Alice de Newburgh m. William, Baron de Mauduit
Isabel de Mauduit m. William, Baron de Beauchamp
William de Beauchamp
Isabel de Beauchamp m. Sir Patrick de Chaworth
Maud Chaworth m. Henry Plantagenet, Earl of Leicester
Mary Plantagenet m. Henry Percy
Maud Percy m. Sir John Neville
Anne Neville m. Sir Thomas Blount, Lord Montjoy
Elizabeth Blount m. Arthur, Baron Wyndsore
Edith Wyndsore m. George Ludlow
Thomas Ludlow
Roger Ludlow, Governor of Massachusetts
Gabriel Ludlow
Sarah Ludlow m. Sir John Carter
John Carter m. Elizabeth Hall
Charles Carter m. Anne Butler Moore
Anne Carter m. General Henry Lee
ROBERT E. LEE

HENRY ADAMS

A typical New England lineage of its kind is that of the descendants and forbears of Abigail Smith, the broad-minded and efficient wife of our second president. Unlike the Hanks-Lincoln series, none of the Adams line ever knew poverty, or was deprived of the education which enables a man of parts to reach his highest possible development.

Robert de Bellomont, Earl of Leicester, m. Isabel de Vermandois
Robert de Bellomont, Earl of Leicester
Margaret de Bellomont m. Saier de Quincy, Earl of Winchester
Roger de Quincy, Earl of Winchester
Margaret de Quincy m. William de Ferrers, Earl of Derby
Anne de Ferrers m. John Grey, Baron de Ruthyn
Maude de Grey m. Sir John de Norville
John de Norton
John de Norton
Richard Norton
William Norton
Rev. William Norton (Ipswich, 1630)
Rev. John Norton
Elizabeth Norton m. Col. John Quincy
Elizabeth Quincy m. Rev. William Smith
Abigail Smith m. John Adams, President of the United States
John Quincy Adams m. Louisa Catherine Johnson
Charles Francis Adams m. Abigail Brown Brooks
HENRY ADAMS

JONATHAN EDWARDS

The ablest of the uncompromising theologians of Puritan blood was undoubtedly Jonathan Edwards.[2] His lineage is fairly typical, differing but little in its general lines from that of the others whose pioneer forbears built up Massachusetts and, through New England, the United States as it is.

Robert de Bellomont, Earl of Leicester, m. Isabel de Vermandois
Elizabeth de Bellomont m. Gilbert de Clare, Earl of Pembroke
Richard de Clare, "Strongbow," Earl of Pembroke
Isabel de Clare m. William le Maréchal, Earl of Pembroke
Eve de Maréchal m. William, Baron de Braose
Maude de Braose m. Roger, Baron Mortimer
Edmund, Baron Mortimer
Roger, Baron Mortimer
Edmund Mortimer
Roger, Baron Mortimer, Earl of March
Catherine Mortimer m. Thomas de Beauchamp, Earl of Warwick
Thomas de Beauchamp, Earl of Warwick
Richard de Beauchamp, Earl of Warwick and Albemarle
Margaret de Beauchamp m. Sir William Cavendish
Sir Thomas Cavendish

[2] "She had the hard, cold Edwards blood
Within her veins, and so she died." (Bret Harte)

Sir William Cavendish
Frances Cavendish m. Sir Henry Pierrepont
William Pierrepont
Rev. James Pierrepont, of Ipswich, Mass.
Sarah Pierrepont m. Rev. Jonathan Edwards, President of the College of New Jersey
JONATHAN EDWARDS, President of Union College

From the brothers and sisters of Jonathan Edwards have descended a remarkable group of university professors and executives:

Daniel Coit Gilman, President of Johns Hopkins
Merrill Edwards Gates, President of Rutgers
Timothy Dwight, as well as his grandson of the same name, and Theodore Dwight Woolsey, Presidents of Yale
Sereno Edwards Dwight, President of Hamilton
Egbert Coffin Smith and Edward Amasa Park, Presidents of Andover
Nicholas Murray Butler, President of Columbia
Aaron Burr, President of the College of New Jersey
Aaron Burr, Jr., Vice President of the United States
Theodore William Dwight, founder of the Columbia Law School
Charles Sedgwick Minot, of the Harvard Medical School
Theodore Roosevelt,[3] President of the United States

SARAH LOUISE KIMBALL

As illustrative of the genealogy of the rank and file of cultivated Americans, I present below that of the recorder of Isabel's progeny.

William de Warren, Earl of Warren and Surrey, m. Isabel de Vermandois
Gondred de Warren m. Roger de Bellomont de Newburgh
Waleran, Earl of Warwick
Alice de Newburgh m. William, Baron Mauduit
Isabel de Mauduit m. William, Baron Beauchamp
William de Beauchamp, Earl of Warwick
Isabel de Beauchamp m. Sir Patrick de Chaworth
Maud de Chaworth m. Henry Plantagenet, Earl of Lancaster and Leicester
Mary Plantagenet m. Henry Percy
Henry Percy m. Margaret Neville
Maud Percy m. Sir John Neville
Sir Ralph Neville, Earl of Westmoreland, m. Margaret Stafford
Joan Plantagenet m. John, Baron Mowbray
Sir Thomas Mowbray, Duke of Norfolk, m. Elizabeth Fitz-Alan
Margaret Mowbray, Duchess of Norfolk, m. Sir John Howard
Sir John Howard, Duke of Norfolk
Catherine Howard m. Sir John Bourchier, Lord Berners
Joanne Bourchier m. Edmund Knyvet
Anne Knyvet m. Richard Sayer
John Bourchier Sayers m. Marie Lamoral van Egmont
Richard Sears (Plymouth, 1630)
Deborah Sears m. Zachariah Paddock
Zachariah Paddock
Peter Paddock
Bethial Paddock m. David Crosby
Deborah Crosby m. Dr. Hezekiah Hyatt
Mary Louise Hyatt m. Col. Simeon DeWitt Clough
Mary Anne Clough m. Charles Bradbury Kimball
SARAH LOUISE KIMBALL

[3] Through the Edwards-Tyler-Roosevelt line.

FREDERICK ELDERKIN FARR

In support of my statement that the average New England farmer has as good a claim to royal blood as any house in Europe, I now set forth a characteristic example, one of which adequate records are available to me,—that of Mr. Frederick Elderkin Farr, late of Wethersfield, now of Perry, New York, a worthy man not essentially different from the body of his fellows. And the reader will at once observe that the following series is for a long period identical with that of Washington, Lincoln, and George V.

Robert de Bellomont, Earl of Leicester, m. Isabel de Vermandois
Elizabeth de Bellomont m. Gilbert de Clare, Earl of Pembroke
Richard de Clare, "Strongbow," Earl of Pembroke
Isabel de Clare m. William le Maréchal, Earl of Pembroke
Eve de Maréchal m. William, Baron de Braose
Maude de Braose m. Roger, Baron Mortimer
Edmund, Baron Mortimer
Roger, Baron Mortimer
Edmund Mortimer
Roger Mortimer, Earl of March
Edmund Mortimer, Earl of March
Elizabeth Mortimer m. Sir Henry Percy, "Hotspur," Earl of Northumberland
Henry Percy, Earl of Northumberland
Margaret Percy m. Sir William Gascoigne
Elizabeth Gascoigne m. Gilbert de Talboys
Sir George de Talboys
Anne de Talboys m. Sir Edward Dymoke
Arthur Dymoke
Edward Dymoke
Thomas Dimmock (Barnstable, 1640) m. Ann Hammond
Shubael Dimmock m. Joanna Bursley
Thankful Dimmock m. Edward Waldo
Edward Waldo m. Abigail Elderkin
Zachariah Waldo m. Elizabeth Wight
John Elderkin Waldo m. Beulah Foster
Anne Waldo m. David Hawley
Diantha Hawley m. Samuel Farr
FREDERICK ELDERKIN FARR

2

But by way of cumulative evidence on the origin of the Puritan farmer, I herewith present a second Farr line, this one leading back to Ada de Warren, youngest child of Isabel de Vermandois.

William de Warren, Earl of Warren and Surrey, m. Isabel de Vermandois
Ada de Warren m. Henry of Scotland, Earl of Huntingdon
Margaret de Warren m. Humphrey de Bohun IV, Earl of Hereford and Essex
Henry de Bohun
Humphrey de Bohun V, "the Good," m. Matilde Exouden
Humphrey de Bohun VI m. Eleanor de Braose
Humphrey de Bohun VII m. Maud de Fiennes, descendant of Hugh Capet and of Charlemagne
Humphrey de Bohun VIII m. Elizabeth de Plantagenet, Countess of Holland, daughter of King Edward I and Eleanor of Castile
Lady Margaret de Bohun m. Sir Hugh de Courtenay, Earl of Devon

Edward Courtenay, Earl of Devon, m. Emiline D'Auney
Sir Hugh Courtenay m. Maud Beaumont
Margaret Courtenay m. Sir Theobald Grenville
Sir William Grenville m. Philippa Bonville
Thomas Grenville m. Elizabeth Gorges
Sir Thomas Grenville m. Elizabeth Gilbert
Sir Roger Grenville m. Margaret Whitleigh
Amy Grenville m. John Drake
Robert Drake m. Elizabeth Prideaux
William Drake m. Philippa Denys
John Drake, of Windsor, Conn. (Boston, 1636) m. Elizabeth Rogers
Elizabeth Drake m. John Elderkin
John Elderkin, Jr., m. Abigail Fowler
Colonel John Elderkin m. Susannah Baker
Abigail Elderkin m. Edward Waldo, Jr.
Zachariah Waldo m. Elizabeth Wight
John Elderkin Waldo m. Beulah Foster
Anne Waldo m. David Hawley
Diantha Hawley m. Samuel Farr
FREDERICK ELDERKIN FARR

3

Another series of records[4] carries Mr. Farr's line still farther back to the very beginnings of royalty in both England and France, a conspicuous lineage which, however, if all the facts were known, would be seen to be shared by most Englishmen and Americans.

Egbert of Wessex, first King of England, m. Lady Radburga
Ethelwulf m. Lady Osburga
Alfred the Great m. Lady Alswitha
Alfritha m. Baldwin II, King of Jerusalem, great grandson of Louis le Debonaire, son of Charlemagne
Arnolph I, Count of Flanders, m. Adela de Vermandois
Baldwin III, Count of Flanders, m. Mathilde of Savoy
Arnolph II, Count of Flanders, m. Rosalie d'Ivrée
Baldwin IV, "le Barbu," Count of Flanders, m. Ogive de Luxembourg
Baldwin V, the Pious, Count of Flanders, m. Adela of France
Mathilde m. William I, the Conqueror
Henry I, Beauclerc, m. Maud of Scotland
Mathilde d'Anjou m. Geoffroy Martel Plantagenet
Henry II m. Eleanor D'Aquitaine
John, King of England, m. Isabella de Taillefer, daughter of Aymar de Taillefer and Lady Alice de Courteney
Henry III (1216) m. Eleanor de Berenger of Provence
Edward I m. Eleanor of Castile, daughter of Ferdinand III, San Fernando Rey d'España
Elizabeth Plantagenet m. Humphrey de Bohun VII
Margaret de Bohun m. Hugh de Courteney, Earl of Devon
Edward Courteney m. Emeline D'Auney (Dawney)
Sir Hugh Courteney m. Maud Beaumont
Margaret Courteney m. Sir Theobald Grenville
Sir William Grenville m. Philippa Bonville
Thomas Grenville m. Elizabeth Gorges
Sir Thomas Grenville m. Elizabeth Gilbert
Sir Roger Grenville m. Margaret Whitleigh
Amy Grenville m. John Drake
Robert Drake m. Elizabeth Brideaux
William Drake m. Phillippa Denys
John Drake (Boston, 1636) m. Elizabeth Rogers
Elizabeth Drake m. John Elderkin
John Elderkin m. Abigail Fowler

[4] Drawn from the extensive compilations of my brother-in-law, the late Edward J. Edwards.

Abigail Elderkin m. Edward Waldo
Zachariah Waldo m. Elizabeth Wight
John Elderkin Waldo m. Beulah Foster
Ann Waldo m. David Hawley
Diantha Hawley m. Samuel Farr
Frederick Elderkin Farr

I now cite a few more of the leading American descendants of Isabel de Vermandois, surnames only being given. (It is understood, of course, that a change in surname indicates descent through a daughter whose children carry the father's name.)

Nathaniel Bacon: Bellomont, de Clare, Meschines, Bacon for six generations, Thorpe, Bacon again for nine generations.
Phillips Brooks: Bellomont, de Clare, Maréchal, Mortimer, Percy, Gascoigne, Markenfield, Mauleverer, Kaye, Saltonstall, Cotton, Brown, Brooks. Francis Parkman and Edward Everett also go back to the same (Brooks) group.
William Ellery Channing: Bellomont, de Quincy, Zouche, de Vere, Grey, D'Arcy, Dighton, Woodbridge, Remington, Ellery, Channing.
George Dewey: Bellomont, DeQuincy, Umfraville for six generations, Lambert, Lyman for seven generations, Dewey for eight generations.
Charles William Eliot: Bellomont, DeQuincy, Ferrers, Berkeley, Pynchard, Bassett for eleven generations, Deighton, Dudley, Atkins, Eliot.
Ulysses Simpson Grant: Bellomont deClare, Maréchal, Braose, Mortimer, Beauchamp, Minor, Clinton, Booth, Grant. The same series leads from Grant through Marsh-Watson to Richard H. Dana.
Benjamin Harrison: Lineage identical with that of Lee except for the last surname.
Patrick Henry: Bellomont, deClare, Sutherland, Sinclair, Stuart, Robertson, Henry.
Oliver Wendell Holmes: Bellomont, de Quincy, Zouche, de Vere, Grey, D'Arcy, Yorke, Dudley, Bradstreet, Wendell, Holmes—a line duplicated by that of Wendell Phillips up to the last surname.
Thomas Jefferson: Bellomont, de Quincy, Zouche, de Vere, Isham, Randolph, Jefferson.
J. Pierrepont Morgan: Warren, Newburgh, Mauduit, Beauchamp, Plantagenet, Percy, Somerset, Vaughan, Morgan for eleven generations.
John Davison Rockefeller: Warren, Newburgh, Mauduit, Beauchamp, Plantagenet, Percy, Neville, Brooks, Wyatt, Pole, Hastings, Clinton, Humphrey, Palmes, Avery, Rockefeller.
William Thompson Sedgwick: Bellomont de Clare, Maréchal, Braose, Mortimer, Beauchamp, Cavendish, Pierrepont, Edwards, Dwight, Sedgwick.

Two generalizations stand out in studies of this kind; first, that of the boundless range of combinations possible from the same essential traits or "unit characters"; second, the gradual rise in importance of the self-respecting middle class which slowly but surely develops at the expense of those artificially maintained as master or serf under the caste system. As to the first, each is the sum of his own combination of developed unit characters. Never yet were any two people exactly alike; Nature has infinite variety at her disposal. Among all these combinations, one, here and there, spells true distinction, and from humble (though never feeble) ancestry spring many of our greatest, "the elements so mixed in them" that the blend is especially favorable. For originality rests not on new traits but on new adjustments of the old.

STUDIES IN INFANT PSYCHOLOGY[1]

By Dr. JOHN B. WATSON and
ROSALIE RAYNER WATSON
NEW YORK CITY

AT no previous time in the history of the human race has so much interest centered in the life and growth of the infant. One sees evidence of this in the development of various organizations and institutions for furthering the bodily welfare of the child; in the fact that kindergartens are admitting younger and younger children; and in the fact that the whole field of preventive medicine is focusing more and more upon the study of methods by means of which the infant and the child may be kept free from disease. At a recent conference of physicians and psychologists held for the purpose of discussing the feeding and the care of infants and their medical and psychological study, the remark was often made, albeit somewhat grudgingly, "it seems astonishing but true that everything in the last three years in medicine and psychology has been headed toward the infant." From the moment of birth and even before his advent the young human animal is looked after from every material standpoint in a way which would have made our frontier ancestors, who simply let their babies grow, doubt our sanity.

The conviction is growing, however, and rapidly, that our knowledge is still too scanty to enable us to care properly for all phases of the welfare of the infant and child. Pediatricians, dieticians and even general practitioners have had the conclusion forced upon them that merely keeping the bottle plentifully supplied with modified cow's milk or feeding the infant with some new form of "balanced diet" combined with a little welfare work in the home, has not prevented a

1 This manuscript was prepared on the basis of the experimental work done in the psychological laboratory of Johns Hopkins University in the years 1919 and 1920. We are greatly indebted to Dr. John Howland and to Dr. J. Whitridge Williams, of the Johns Hopkins Hospital, for making this study possible.

Acknowledgement should be made to the Committee on Grants for Research of the American Association for the Advancement of Science for assistance in making these studies. In 1917 the Committee on Grants upon recommendation of Dr. J. McKeen Cattell appropriated the sum of $100.00 for our assistance in studying the development of reflexes and instincts in infants.

The work at Hopkins was left in such an incomplete state that verified conclusions are not possible; hence this summary, like so many other bits of psychological work, must be looked upon merely as a preliminary exposition of possibilities rather than as a catalogue of concrete usable results.

high rate of infant mortality. Nor have we any guarantee even if the body weight is kept normal by any form of diet other possibly than the mother's milk that the infant will develop properly along psychological lines. And by psychological in this connection we mean the plain matters of common occurrence such as crawling, walking, sitting up, beginning to speak, smiling, blinking, reaching, imitation, the putting on of habits, the expression of emotional activity, and the like. It lies very well within the bounds of possibility that a diet and régime which will keep up the body weight might nevertheless cause an infant to put on its various necessary activities at a very slow rate or possibly at a too rapid rate. This might end in giving us either a child or an adult with a very unbalanced and unstable disposition or an indolent or phlegmatic one. Research work along many lines—nutritional, glandular, the effects of difficult labor, inheritance, and the psychological study of infant activity—is called for from our best qualified men.

On the psychological side our present knowledge of infant life is almost *nil*. If an anxious mother wishes to determine whether her infant is developing normally along psychological lines there are no data at present to guide her and no individual or institution to whom she may turn to get a reasonable answer. Who would pretend to say what the activity chart or stream of activity of a three months', six months' or year old child should reveal? The ordinary doctor will say, "Don't worry about the infant, it is getting along all right. Anyway it is too young for anybody to tell much about it." Nor is this let-alone policy confined solely to the general practitioners. Even our educators do not escape it. A prominent professor of education once said to us, "You will find when you have taught as many children as I have that you can do nothing with a child until it is over five years of age." Our own view after studying many hundreds of infants is that one can make or break the child so far as its personality is concerned long before the age of five is reached. We believe that by the end of the second year the pattern of the future individual is already laid down. Many things which go into the making of this pattern are under the control of the parents, but as yet they have not been made aware of them. The question as to whether the child will possess a stable or unstable personality, whether it is going to be timid and beset with many fears and subject to rages and tantrums, whether it will exhibit tendencies of general over or under emotionalism, and the like, has been answered already by the end of the two year period.

There are several reasons why the minute psychological study of infant life is important. (1) As was pointed out there are no standards of behavior or conduct for young infants. Our own experi-

mental work which, even at the end of two years is just beginning, has taught us that the study of infant activity from birth onward will enable us to tell with some accuracy what a normal child at three months of age can and should do and what additional complexities in behavior should appear as the months go by. Psychological laboratories in many institutions ought to be able to make cross-sections of the activity of any infant at any age and tell whether the streams of activity are running their normal course and whether certain ones are lagging or have not even appeared. After sufficient work has been done to enable us to have confidence in our standards we should be able to detect feeble-mindedness, deficiencies in habit, and deviations in emotional life. If a proper analysis of the activity streams can be made at a very early age the whole care of the child may be altered with beneficial results. (2) Modern psychology catalogues most elaborate lists of instincts and emotions in human beings. These catalogues are not based upon experimental work but upon the preconceived opinions of the men making up the lists. At present we simply have not the data for the enumeration of man's original tendencies and it will be impossible to obtain such data until we have followed through the development of the acitvity of many infants from birth to advanced childhood. Children of five years of age and over are enormously sophisticated. The home environment and outside companions have so shaped them that the original tendencies can not be observed. The habits put on in such an environment quickly overlay the primitive and hereditary equipment. A workable psychology of human instincts and emotions can thus never be attained by merely observing the behavior of the adult. (3) By reason of this defect the study of vocational and business phychology is in a backward state. The attempt to select a vocation for a boy or girl in the light of our present knowledge of the original nature of man is little more than a leap in the dark. High sounding names like the constructive instinct, the instinct of workmanship and the like, which are now so much used by the sociologists and the economists, will remain empty phrases until we have increased our knowledge of infancy and childhood. The only reasonable way, it would seem to us, of ever determining a satisfactory knowledge of the various original vocational bents and capacities of the human race is for psychologists to bring up under the supervision of medical men a large group of infants under controlled but varied and sympathetic conditions. Children begin to reach for, select, play with and to manipulate objects from about the 150th day on. What objects they select day by day, what form their manipulation takes, and what early habits develop upon such primitive instinctive activity should be recorded day by day in black and white. There will be marked individual differences in the material selected, in the length of

time any type of material will be utilized, and in the early constructive habits which will arise with respect to all materials worked with by the infant. Without instruction one infant (eighteen to twenty months in an observed case) will build a neat wall with her blocks, with one color always facing her. If the block is turned while she is not looking she will quickly change it and correct the defect. In other children such a bit of behavior can be inculcated only with the greatest difficulty. Still another child can not be made to play with blocks but will work with twigs and sticks by the hour. Variations in the election and use of materials are the rule in infancy but until we have followed up the future course of such variations upon *infants whose past we have watched day by day* we are in no position to make generalizations about the original tendencies which underlie the vocations. (4) Finally, until we have obtained data upon the emotional life of the infant and the normal curve of instinctive and habit activity at the various ages, new methods for correcting deviations in emotional, instinctive and habit development can not be worked out. Let us take a concrete example. A certain child is afraid of animals of every type, furry objects, the dark, etc. These fears are not hereditary. Our experiments will be convincing upon that point. What steps can we take to remove these fears, which unless they are removed in infancy, may become an enduring part of the child's personality?

An Experimental Study of what Infants can do at Different Ages. Instincts and Early Habits

The human infant in general is sturdy and well able to stand all of the simple tests we need to apply. Certainly the stresses and strains upon his nervous system, the muscular pulls and twists he gets in merely being born are a thousand times harder upon him than anything we will later do to him in the laboratory. Probably none of our tests is any more strenuous for him than giving him his morning bath or changing his clothes. We have worked upon more than five hundred infants and so far without the slightest temporary or permanent mishap. These remarks seem necessary in view of the fact that sentimentalists sometimes feel when visiting our laboratory that our work may be a little hard on the infant. The work is done under the constant supervision of physicians and we take the stand that what we are doing will be important in the long run in lessening human misery and maladjustment.

When the newborn infant is first brought into the laboratory and undressed most visitors exclaim: "What can you see to study in that highly unstable but wholly delightful bit of helpless protoplasm?" Observation does seem all but hopeless at first. But closer inspection soon makes it clear that there are many forms of infant adjustment which can be studied easily under controlled experimental conditions.

Our first problem in the psychological study of the infant was the finding out of those activities that can be seen at birth and those that appear as the infant increases in age. Which among those activities drop out or change as age advances? What is the significance for the later make-up of the individual of those that remain in the stream? How are they tied together so as to form suitable bases for the putting on of the stable and constructive habits of the adult? We can possibly present our problem and our methods by considering a few of the activities as they appear under laboratory scrutiny.

Grasping. One of the easiest things to note about the new born human infant is that when any small object such as a stick, a tuft of hair, or a finger is placed in the palm, its fingers close down upon the object and clasp it tightly. For experimental purposes we used a small twisted wire rod covered with a piece of rubber tubing. The infant's fingers are open, the rod is placed in the palm and a gentle shake administered, whereupon its grasp of the rod tightens. The experimenter then catches the two ends of the rod and raises the child up over a soft mattress. One assistant takes the time that the infant hangs suspended while a second assistant puts both hands under it to catch it when it lets go. The evidence seems to be good that all but about two per cent. of normal infants of average weight at birth can suspend themselves for an appreciable interval of time. Many of them will hang suspended for only a fraction of a second while others will hang suspended for many seconds. The longest suspension we have had was one minute. Often times the infant is made to suspend itself with difficulty. In such cases it is emotionally aroused by holding the head, feet or legs or by holding the nose for an instant. If a good healthy cry is started the muscular strength seems to be increased. Whether this bears out Cannon's contention that the major emotions such as fear and rage are biologically serviceable can possibly not be concluded from these experiments. His view is that under the influence of stimuli that produce the major emotions a greater than normal amount of adrenalin is set free by the adrenal glands (one of the so-called ductless glands). This adrenalin attacks the stored sugar in the liver (glycogen) setting it free in the blood stream in such a form that it can serve rapidly as food for the muscles and for neutralizing fatigue products in the muscles. At any rate the fact remains that in many cases when the sluggish infant can be stirred up emotionally it can be made to suspend itself on the rod.

This instinctive reaction undoubtedly begins before birth since it is present in children born prematurely. We have followed it through day by day on a great many children. The daily time of suspension varies greatly. It does not seem to increase or decrease with the age of the child in any regular way. The most significant fact for the

work we are engaged in is that the instinct disappears at about the age of one hundred and twenty-four days, although in some infants it persists to a greater age. Once it disappears from the stream of activity under normal conditions it never returns. It will be seen here at once that this observation of the grasping instinct gives us one of our desirable points. If we take a cross-section of the activities of the child at any time from birth to one hundred and twenty-four days, we shall find this instinct present. After the period of its disappearance, not yet exactly determined, the behavior of the infant would give no evidence that such an instinct had ever been present. Having determined what is called a normal distribution curve for the disappearance of this instinct in normal children, it will be seen that we have a basis or standard for testing infants whose development seems to be delayed; for example, comparing with presumably normal infants, infants whose parents are feeble-minded, since we know that a large percentage of the infants of feeble-minded parents will turn out to be feeble-minded. We are not yet ready to advise the practical use of this test. Our work progressess slowly by reason of the fact that normal infants suitable in age are difficult to obtain in the laboratory and infants suspected of abnormality are still more difficult to obtain. What slender evidence we have would seem to show that in these suspected cases this primitive instinct persists for a much longer time than it does in the supposedly normal infants. A word of warning should be introduced here in order that mothers may avoid needless anxiety in case they find that their infants possess the grasping instinct at a much later age than we have indicated as being the usual one. Our work has not gone far enough for us to say that even if the instinct is present at one hundred and seventy-five days of age the infant must necessarily be abnormally slow in development. One should not draw any conclusions on the basis of either the presence or the absence of any one such hereditary form of activity. It is only when we have established workable standards for many such modes of behavior and find deviations from these norms in many particulars that alarm need be felt.

Reaching. As soon as the grasping reflex begins to disappear a much more serviceable form of activity, partly hereditary and partly *learned* (habit), begins to take its place, and that is extending the hand for an object, grasping it, and carrying it to the mouth or manipulating it. This is probably the most fundamental group of activities appearing in man. Tests for reaching are begun at one hundred days of age. The subject is seated in the lap of an assistant in a well lighted room. The experimenter takes a stick of candy and slowly extends it toward the infant. After the lips have been touched with the candy several times the sight of it, even before the reaching stage is attained. will

tend to bring about heightened activity, especially of the hands. As the days go by this activity becomes greater and at one time or another the experimenter will find, if his patience is sufficient, that the infant will slap the inside of the palm against the candy, will grasp it and carry it towards the face. When this happens the subject is always allowed to suck the candy for just an instant. The candy is then removed and the test repeated. Five or six such tests are given on each weekly experiment. The growth of this combined instinct and habit activity is extremely instructive to watch. In normal infants at one hundred and fifty days who have had weekly practice for several weeks the reaction is fairly definitely established. At that time almost any object will be reached for. One of the most significant factors appearing is that apparently the infant is positive to all objects, that is it reaches out for practically every object and avoids none. With slight exceptions all avoiding reactions, that is drawing back or turning from objects, have to be learned. This can be illustrated very nicely with the lighted candle. We usually establish the reactions of reaching for the candy and avoiding the candle flame at the same time. If the candle is made to approach the infant's face the same eager random activity is exhibited as to the candy. Care is taken always not to allow the hand to come close enough to produce a burn. But the hand is allowed on every trial to be momentarily touched by the flame. This produces a slight reflex withdrawal of the finger, sharp closing, fanning or spreading of the fingers, etc., and, if the temperature is too great, an actual reflex withdrawal of the arm. The candle is then hid for a moment and the child again stimulated. The growth of this activity is very similar to that of reaching for the candy. It takes not one slight burn of the candle but many before the infant learns to let its hands hang at its sides when the candle gets within reaching distance. Possibly if the burn were made severe enough only a few such tests would be required (a "conditioned reflex" would arise instead of the ordinary habit).

Another feature of the reaching reaction has been worked out and that is the distance to which the child will reach for objects. When we started our studies we believed with the poet that the child would reach for any object coming within its ken regardless of the actual distance of the object. Much to our surprise we found that in no case were objects reached for, even when fixated and followed with the eyes, at a greater distance than twenty inches. When a lighted candle is brought slowly across the room and extended toward an infant which has just learned to reach, the hands and arms do not begin to get active until the candle is twenty-five inches from the face. The body then begins to bend toward the object and finally as it is brought nearer still the hands and fingers take on the proper adjustment for grasping; actual reaching then soon follows.

We thus see that in the study of reaching we obtain another point on our infant activity chart. An infant tested at one hundred and fifty days should have as a part of its equipment the ability to reach for objects, to grasp them and to carry them to the mouth or otherwise manipulate them, and the ability to learn to avoid a candle or other harmful stimuli provided proper training has been instituted.

Right- and Left-handedness. At the present time a good deal of interest is manifested in the question as to whether handedness is hereditary or whether it is simply a learned response. The discussion so far has been of the "arm chair" variety. Most individuals are right-handed and it is natural to suppose that we would try to instil in youngsters almost from the beginning the dominance of the right hand. We bring this about possibly even without trying to by handing objects toward the child's right hand, by shaking its right hand, patting its right hand, and by leaving its right hand free in carrying it in our arms. Does this behavior on our part simply carry on right-handedness traditionally or is there something hereditary and instinctive about this reaction? The problem is both an interesting one scientifically and at the same time a practical one since it cuts deep into actual school procedure. All children are told when they come to writing, "Now take your pencil in your right hand." We do not wish to criticise such a custom in the light of our present knowledge. We know that most children thrive more or less well under such a procedure. On the other hand there is a slight but growing body of evidence to show that in some children at least stammering and other emotional mishaps may result when a child has for whatever reason predominantly used its left hand and has been forced to change over to the right. In some cases the bad symptoms disappear if the child is allowed to go back to the free use of its left hand.

We have carried through a rather wide series of studies, not yet completed, however, upon the problem of handedness. Our thesis for the moment is: If the predominant use of one hand is an instinctive and hereditary matter from birth onward, it would be better to let the child learn to use the hand in line with its instinctive endowment. On the other hand if no such instinctive factor is present it would be less embarrassing for the child in most situations if it were forced to use the right hand. In order to test this matter we made a careful study upon twenty infants of the length of time they could hang suspended with the right and left hands. Each of the infants was brought into the laboratory at birth and each day thereafter for a period of ten days and tested. Our results show conclusively that the infant does not suspend itself on the average with the right hand for a longer time than with the left. As a matter of fact the total time of suspension for the ten days was exactly the same for the two hands.

In order to make our results more conclusive still we devised a small "work adder" by means of which the random slashing movements of the infant could be recorded. A cord is attached at one end to the infant's wrist and at the other to a small escapement device which when operated caused a toothed wheel to revolve always in one direction. To the toothed wheel is connected a small drum. A cord bearing a small lead weight is fastened to the drum. As the infant makes its random movements this weight is wound higher and higher from the ground. Such an apparatus is of course attached simultaneously to each wrist. At the end of five minutes the experiment is stopped and the height to which the weights have been wound up from the floor is measured. The same twenty infants whose grasping reflex was tested were used in this experiment. This method gave us abundant opportunity to determine experimentally whether one hand was used more than the other. Our results show that the amount of work done on the work adders is almost identically the same for the two hands (the difference is less than P. E.) if the work of the two hands for the whole ten days is averaged. On any one day there was a disparity in the amount of work done with the two hands, but an infant markedly right-handed today is just as likely to be left-handed tomorrow.

One other step has been taken in the attempt to settle the problem of handedness. Infants from about one hundred and fifty days to one year of age have been tested once each week to find out which hand was first used in reaching for objects. On each weekly test from ten to twenty trials were given. A stick of peppermint candy or a candle was generally used as a test object. The object was brought slowly toward the face of the infant. At the proper distance reaching finally occurred. An assistant recorded on each trial the hand first used and if both hands were used, as was often the case, which one first touched the object. Again our tests fail to show any predominant use of either hand. So that we must conclude, albeit tentatively, that there is yet no evidence for assuming a hereditary basis for handedness.

This result seems to be confirmed by the anatomical measurements we have recently made (so far upon only one hundred infants). The length of the forearm to the tip of the middle finger is measured very accurately with a device which resembles somewhat the instrument that is used for measuring the length of the foot in shoe stores. The breadth of the wrist likewise is measured with calipers and the width of the palm at the knuckles. In these one hundred cases, which we admit are too few for any certain conclusion, we find almost no difference betwen right and left measurements.

Early Eye Movements. This excursion into the field of our studies upon right-and-left-handedness has taken us a little aside from our main problem which was to show the course and development of those

instinctive movements which will yield us an activity chart. Early eye movements furnish us with at least three definite new points on this chart. The eye movements of the infant are not difficult to study. The infant is placed upon its back with the face held lightly in a vertical position by the observers. Immediately above the baby's head is suspended a perimeter carrying a small light. This perimeter looks like the half of a barrel hoop. The light is thus always equi-distant from the baby's eye. It can be made to appear first on the left side and then on the right. We start with it usually on the left. In a second or two after the light is turned on the infant's eyes swing to the lighted side. There is no fixation in the strict sense of the word but all of the roving movements of the eyes take place in the lighted field. As soon as the eyes have swung over the light is turned out, shifted to the right and again lighted. In a few seconds the eyes swing slowly over to the right. This reaction seems to take place with the same regularity as do the responses to light of lower organisms. Indeed, we have called it the tropism-like response of the human eye. This reaction takes place equally well but more slowly if one eye is screened from the light. At a fairly definite time, which we are not yet ready to state, this response seems to disappear and something corresponding to definite fixation occurs. At that later age the infant begins to focus upon objects. To test this second type of eye movement the infant is placed in a sitting position on an attendant's lap. A lighted candle is then moved to the right side and then over to the left, then up and then down in straight lines. Its eyes fixate the candle and move with it but do not follow the light if it is rotated in a circle. This is the second stage in the development of eye responses. When the candle is held to the right or left, fixation is easier to obtain than when it is placed above or below the eyes. Again fixation is easier to obtain when the candle is held above the eyes than when it is held below them. The third stage is what we have called complete fixation; it occurs, let us say tentatively, around the one hundredth day. The eye of the infant is then able to follow a candle when it is moved in a complete circle. It is worth noting in passing that very few children are born with badly crossed eyes. Occasionally we do find one with the muscular balance so poor that the early tropism response is hard to obtain.

The Babinski Reflex. If the sole of the foot of a normal adult is stroked with the end of a match all five toes show flexion, that is, the toes bend downward toward the ground. On the other hand, in certain pathological cases where there is a lesion in the central nervous system a new type of response appears. When stimulated by the match stick the great toe, instead of showing flexion, shows extension, that is to say, flies upward. The other toes usually spread out like a fan or show the normal flexion described above. This is usually known as the

"sign" or reflex of Babinski. Its presence in the adult is definitely pathological. Strange to say the infant exhibits this reflex. Apparently its presence is due to the fact that there is a lack of complete development of one of the tracts in the central nervous system. It would seem at first sight that its study would give us one of our safest criteria in determining what one might call the activity or developmental age of the child as opposed to its chronological age, since its disappearance does apparently mark the completion of the growth of certain structures in the nervous system. Such seems not to be the case, however. It is a most variable type of response. We have made many hundreds of tests on children from birth to three years of age. In rare cases it is absent from birth. In certain other cases it can be obtained in one foot and not in the other. Sometimes it can be obtained on one day and not on the next. Again it disappears at a very variable age. It is ordinarily said that the Babinski reflex disappears around six months of age. Here are a few actual figures:

0 to 3 months,	24 cases observed,	present in 21 cases,	absent in 3
4 to 6 months,	8 cases observed,	present in 6 cases,	absent in 2
7 to 12 months,	12 cases observed,	present in 7 cases,	absent in 5
Over 1 year,	6 cases observed,	present in 1 case,	absent in 5

These do not represent all of our results but merely those obtained from a rather homogeneous group. The indication on these few cases is that it is absent or approaches senescence at one year of age or thereabouts. It would thus seem that the Babinski can never be used as any safe kind of guide in determining the normal activity age of infants. Nevertheless if it persists to a much greater age than one year one should want to make a pretty thorough examination of the whole reflex and instinctive equipment.

Sitting Alone. The ability to sit alone is an extremely important index of development, comparable probably in all respects to reaching. In order to study progress in this act the infant is placed in a sitting position on a hard mattress with legs outstretched at a given angle. Tests are usually begun at about one hundred days of age. We give below the progress of one infant. The first evidence that sitting alone was possible was obtained at 138 days. She fell over in 2 minutes and 12 seconds to the right side. It was found that if the infant was stimulated by holding some object in front of her or by getting the mother to cause her to smile and reach out her hand the sitting position could be maintained for a longer period of time than if she were left alone. On the 150th day, while the infant did not sit up for a longer period of time, she began to pull at her sock, leaned over and touched the foot with nose and mouth, and looked around, sitting up the while. On the 159th day she sat up steadily, played with her toes, used the hands in striking the mattress, then gradually sagged forward, drop-

ping at the end of 4 minutes. She was making steady progress in this response when one day at home, while sitting alone, she fell over backward and struck her head on a stone, producing a coma-like state which lasted for an hour and a half. This one experience markedly delayed her progress in sitting alone. We have noticed the same thing when children are learning to stand and to walk. If the child has a fall or a mishap while standing it is likely to cry when again placed in a standing position and almost immediately begin to "feel" its way to the ground without attempting to put forth the best that is in it. While our records are few we should say that most infants so far studied are able to sit up for a short length of time at the age of six months.

The types of infant behavior so far discussed serve simply to illustrate the purpose and methods of our work. The development of many other instinctive activities is being followed through. We can only briefly indicate some of them. The early defensive responses of children can be quite readily observed. If one pinches slightly the inside of the right knee the left foot is drawn upward and will begin to push at the offender's hand. If the nose is held the hands are thrust upward and strike at the obstructing object. In normal youngsters these responses are quick and active. They are present from birth and persist throughout life. Again, in infants the thumb is useless and lies folded across the palm. At about one hundred days of age in normal infants it can be brought parallel with the forefinger; a little later it can be used like the other fingers in grasping and takes the adult position when the hand and fingers are extended. Blinking is another activity which has a partly defensive function. This response can be obtained by passing the hand or other object rapidly across the baby's eyes and between the eyes and the source of light. Care must be taken to keep from touching the eyebrows or creating a draft of air. Unless these precautions are taken we can obtain blinking from birth; but blinking due to a rapid shadow passing across the eyes can not be obtained earlier than the sixtieth day. In many supposedly normal infants it can not be elicited before the one hundred and twentieth to one hundred and fiftieth day. Crawling is another most important function. Progression of some kind is undoubtedly instinctive, but the form that the progression takes differs markedly in every child and probably depends upon a lack of balance in structural development and partly upon habit factors. Some infants make progress by springs and dives when the leg and waist muscles are well developed. When the arm muscles are better developed progression takes place by using mainly one or both elbows, and if one arm is weaker than the other the child moves in a circle. By degrees, however, it learns to compen-

sate for this and to make progress even though one arm remains weak. As a forerunner of the ability to stand alone and walk one must observe week by week the development of the "extensor thrust" of the leg. At a certain age, which we are not yet ready to fix exactly, this reflex appears. It is easy to observe. Place the infant on its back, take hold of the two hands and pull it slowly to a sitting position and then gradually upward. As soon as any part of the sole of the foot touches the mat a noticeable stiffening of the leg appears and as the whole weight of the infant is borne by the feet the legs suddenly stiffen and take the whole load. In backward children it is unquestionably delayed; in some cases the reflex can not be brought out in children even three and four years of age.

This almost random sampling of our laboratory studies on the instinctive and habit activities of infants teaches us first that there is a wealth of material to observe and study in the infant at every age and that as this material is worked up it becomes useful from both the scientific and the practical standpoint, in the latter case enabling us to tell when an infant, whatever its régime or diet, is progressing properly on the activity side.

Most of our work has been done upon subjects under ten months of age. Observations which we are just beginning on older infants show that here is a very rich and promising field of work in the period lying between ten and twenty-four months. Imitation of varied kinds appears, spoken language begins, standing and walking develop, and then the whole world of objects is examined by the child under his own steam. Here become more marked and complex the varied activities which most immediately show what, for lack of a better term, we may call personality. It is here that we expect to find most of our data on the human being's repertoire of instincts and vocational bents. Again, during this period we shall have our best opportunity for studying methods by means of which we can shape the early habits along desirable lines, socialize the instincts, break up harmful emotional attachments and stabilize the whole of the general system of emotional expression. The second year of childhood development is from our standpoint the one most fraught with possibilities of mishap along emotional lines. For an understanding of the infant's emotional life and how emotional expression becomes linked up with the instinctive and habit activities such as we have just examined, it seems best to turn once more to the laboratory.

Experimental Study of the Emotional Life of Infants

The experimental study of the emotions in adults is in a backward state in psychology. For one reason, emotions seem too evanescent and

too complex for study. They run all the way in complexity from the simple blush of the boy or girl to the violent states we see in love and rage in which the individual is totally unfitted to carry out his ordinary activities. Early in our study of the emotional life of the infant we came to the conclusion that in them the emotional patterns are really quite simple and that the later complexity we see in the adult is brought about by training and environmental influence. But this training has been of an accidental character and under the control neither of the person in whom the emotion was built up nor of his parents and other associates. It seemed worth while to test out this hypothesis experimentally because it is important to bring the emotional life under some kind of scientific and practical control and to do this we must study how the early environment of the child forces emotional states upon him. Such a study it was hoped might result in a practical procedure by the use of which the child's life might be so shaped that undesirable emotions might not be implanted. On the other hand, granting that they had been implanted through carelessness or ignorance of parents and associates, we hoped to find methods by means of which they could be got rid of.

Our earliest observation showed that from birth three fundamental inherited emotional patterns could be observed. Without assuming that our observations are complete we feel reasonably sure that *fear, rage* and *love* are original and fundamental. Our method of observing these emotions is a purely behavioristic one, that is, we make no effort to read into the mind of the child those things which psychologists have attempted to do for so long. We bring the child into the laboratory and stimulate it with those objects which we know will produce emotion in many adults and in nearly all children who have had the ordinary home bringing up. We then note the reaction that takes place. In other words, in any bit of behavior which can be observed there is always a stimulus or object present which calls out a reaction. The psychologist, then, must search for the objects which will call out emotions and then observe the reactions to each so that new forms of emotional expression may be found. We will apply this simple procedure to the infants brought up in the sheltered environment of the hospital where contact with the outside world has been kept at a minimum.

Fear. What are the stimuli (objects or situations) which will bring out fear responses in infants? Our observation shows that the stimuli to fear are quite constant and quite simple. If the infant is held over a pillow and allowed to drop suddenly, the fear response appears. It can be brought out generally by a sudden shake or push or by suddenly pulling the blanket upon which it is lying. We might

group all of these and say that *sudden removal of support* is an adequate stimulus to fear. The other most far reaching and important stimulus is that of a *loud sound;* for example, the striking of a long steel bar with a hammer is one of the most effective means of calling out this response. These are the common stimuli which are present almost daily in the life of every infant. The reaction or response to such stimuli is a sudden catching of the breath, clutching randomly with the hands, the sudden closing of the eyes, and the puckering of the lips followed in some cases by crying. In older children these reactions appear and in addition there is crawling away, running away and in some cases hiding the face. We have found no other stimuli which will call forth fear in the very young infant. It has been often stated that children are afraid of the dark, or animals, of furry objects in general. We shall show later that this is not the case.

Rage. In a similar way we have studied the question as to the original objects and situations which will produce the response of rage. Our observations show conclusively that the *hampering of the infant's movements* is the one stimulus which apart from all training brings out the movements we should characterize as rage. If the head is held lightly between the hands, if the arms are held closely to the sides or if the legs are held tightly together the response appears. The body stiffens and if the arms are free slashing movements of the hands and arms result. If the legs are free the feet and legs are drawn up and down, the breath is held until the child's face is flushed. There is crying at first, then the mouth is opened to the fullest extent and the breath is held until the face appears blue. These states can be brought on without the pressure in any case being severe enough to produce the slightest injury to the child. The experiments are discontinued the moment the slightest blueness appears in the skin. Almost any child can be thrown into such a state and the reactions will continue until the irritating situation is relieved and sometimes for a considerable period thereafter. We have had this state brought out when the arms are held upward by a cord to which is attached a lead ball not exceeding an ounce in weight. The constant hampering of the arms produced by even this slight weight is sufficient to bring out the response. When the child is lying on its back it can occasionally be brought out by pressing on each side of the head with cotton wool. In many cases this state can be observed quite easily when the mother or nurse dresses the child especially in winter clothing.

Love. The study of this emotion in the infant is beset with a great many difficulties on the conventional side. Our observations consequently have been incidental rather than directly experimental. The stimulus to love apparently is the stroking of the skin, tickling, gentle

rocking, patting and turning the child across the attendant's knee on its stomach; it is especially brought out by the stimulation of what, for lack of a better term, we may call the erogenous zones, such as the nipples, the lips and the sex organs. The response in an infant depends upon its state. If it is crying the crying will cease and a smile may appear. In slightly older children there is a gurgling and cooing and in still older children the extension of the arms which we shall class as the forerunner of the embrace of adults. It is thus seen that we use the term "love" in a much broader sense than it is popularly used. The responses we intend to mark off here are those popularly called "affectionate," "good natured," "kindly," etc. The term "love" embraces all of these as well as the responses we see in adults between the sexes. They all have a common origin.

Whether these are all the emotional patterns that are strictly hereditary and not due to training we are not sure, and whether there are other stimuli which will call out these responses we must also leave in doubt; but if our observations are in any way complete it would seem that the emotional reactions are quite simple in the infant and the stimuli which call them out quite few in number. Our own observations did not at first satisfy us because the whole problem appeared too simple and stereotyped. We determined then to continue with our work along a slightly different line. It was our good fortune to have six or seven older children brought up in the hospital under a strict régime. These children varied in ages from about four months to one year. They had had practically no outside contact with the world, having never left the hospital buildings. They had never seen an animal or any of the objects which were later presented to them in the laboratory. All of these children were extremely well and healthy in view of the fact that they belonged to the wet nurses attached to the hospital.

The infants were brought to the laboratory and seated in the lap of the mother or of an attendant. As soon as the infant became still a hitherto concealed live animal was suddenly presented. We can only illustrate two or three such tests and summarize the general results. For example the following experiment was made upon baby T., a girl, 165 days of age:

A very lively, friendly *black cat* was allowed to crawl near the baby. She reached for it with both hands at once. The cat was purring loudly. She touched its nose, playing with it with her fingers. It was shown three times. Each time she reached with both hands for it, the left hand being rather more active. She reached for it when it was placed on a lounge before her but out of reach.

Then a *pigeon* in a paper bag was laid on the couch. The pigeon was struggling, and moving the bag about on the couch and making a scraping

noise. The baby watched it intently but did not reach for it. The pigeon was taken out of the bag on the couch before her, cooing and struggling in the experimenter's hands. She reached for it again and again and failing, of course, to get hold of it put her hands in her mouth each time. She was allowed to touch its head. The pigeon moved its head about with quick, jerking movements. It was then held by its feet and allowed to flap its wings near the baby's face. She watched it intently, showing no tendency to avoid it, but did not reach for it. When the bird became quiet she reached for it, and caught hold of its beak with her left hand.

Test with a rabbit. The animal was put on a couch in front of her. (The child was sitting on her mother's lap). She watched it very intently but did not reach for it until the experimenter held it in his hands close to her; then she reached for it immediately, catching one of its ears with her left hand, and attempted to put it into her mouth.

The last animal presented to her was a *white rat.* She paid little attention to it, only fixating it occasionally. She followed it with her eyes somewhat when it moved about the couch. When held out to her on the experimenter's arm she turned away, no longer stimulated.

April 24, 172 days old. The baby was taken into a dark room with only an electric light behind her (faint illumination). A stranger held the baby. The mother sat where she could not be seen. A dog was brought into the room and allowed to jump up on the couch beside her. The baby watched intently every move the dog made but did not attempt to reach for it. Then she turned her head aside. The front light was then turned up and the dog again exhibited. The infant watched very closely every move the dog and the experimenter made, but did not attempt to catch the animal. She exhibited no fear reactions no matter how close the dog was made to come to her.

The tests were continued by taking the child in its chair to the dark room and building a small bonfire in front of it. The final trial with every child was made by taking it to the zoological park and confronting it with many different types of animals, special permission being accorded us for close inspection of the primates.

Never in any experiment on any child was the slightest fear response obtained. Almost the invariable mode of behavior was a reaching for the object, followed by handling or manipulation. Our results seem to show conclusively that when children are brought up in an extremely sheltered environment, such as never is afforded by the home, fears are not present to other stimuli than those which we have already enumerated.

How can we square these observations with those which show the enormous complexity in the emotional life of the adult? We know that hundreds of children are afraid of the dark, we know that many women are afraid of snakes, mice and insects, and that emotions are attached to many ordinary objects of almost daily use. Fears become attached to persons and to places and to general situations, such as the woods, the water, etc. In the same way the number of objects and situations which can call out rage and love become enormously increased. Rage and love at first are not produced by the mere sight of

an object. We know that later on in life the mere sight of persons may call out both of these primitive emotions. How do such "attachments" grow up? How can objects which at first do not call out emotions come later to call them out and thus enormously increase the richness as well as the dangers of our emotional life?

Until recently no experimental work had been done which would show such emotional attachments in the making. We were rather loath to conduct such experiments, but the need of this kind of study was so great that we finally decided to undertake the building up of certain fears in the infant and then later to study practical methods for removing them. We chose as our first subject Albert B., an infant weighing twenty-one pounds at eleven months of age. We chose him particularly because of his stolid and phlegmatic disposition.

Before turning to the experiments by means of which we built up fears in this infant it is necessary to give a brief description of a method which has recently been developed in psychology, that of the "conditioning of reflexes." If a subject sits with the palm of his hand upon a metal plate and his middle finger upon a metal bar and an electrical current is sent through the circuit thus completed by the hand, the finger will fly upward from the metal bar the moment the electric shock is given. This painful stimulus is thus the native or fundamental stimulus which calls out the defensive reflex of the finger. The sight of an apple or the sound of a bell will naturally not produce this upward jerk of the finger. On the other hand, if the bell is sounded or the colored object is shown the moment the electric current is completed through the hand, and this routine is repeated several times, the situation becomes wholly different. The finger begins to jerk up reflexly now and then when the bell is rung or the colored object shown even if the electrical current is not sent through the hand. After a longer or shorter period of training the colored object will cause the jump of the finger just as inevitably as does the current. This we call a conditioned motor response and we have shown that these conditioned responses persist for long periods of time, in some cases possibly throughout the life of the individual. There is no "reasoning" or "association of ideas" involved, because we can produce conditioned reflexes in very low forms of animals. The same thing occurs in our glands. If one attaches a small apparatus to the parotid gland—one of the salivary glands in the cheek—in such a way that the saliva flows out drop by drop, it can be shown that the direct stimulus of the gland is *actual contact* with some edible or drinkable substance, for example, weak hydrochloric acid, vinegar, etc. The moment such an acid touches the tongue the gland begins to flow profusely. Ordinarily the sight of objects does not produce an increased flow of the glands, but if combined stimulations are given, the object being shown at the same time the acid is given, the sight of the object

finally will produce an increased flow of the gland. This is of course what happens every time food or drink is brought to the mouth. Thus the youngster's mouth has every reason to "water" when a stick of candy is held in front of him or our own when we are hungry and a toothsome morsel is held before our eyes. It is probable that all of our glands, even the so-called ductless ones such as the thyroid or the adrenals, become conditioned by means of such environmental factors throughout our life.

We began to question, with such results as the above in front of us, whether or not entire emotional reactions such as are seen in fear might be conditioned in this simple way. If so we have an adequate way for accounting for the enormous increase in the complexity of adult emotional life as contrasted with its simpler manifestations in infants. To start the experiment it became necessary to use some simple native or fundamental stimulus which *would* produce fear (corresponding to the electrical shock). We have already pointed out that loud sounds are the most potent of all such stimuli. We determined to take Albert and attempt to condition fear to a white rat by showing him the rat and as soon as he reached for it and touched it to strike a heavy steel bar behind him. We first showed by repeated tests that Albert feared nothing under the sun except loud sounds (and removal of support). Everything coming within twelve inches of him was reached for and manipulated. This was true of animals, persons and things. His reaction, however, to the sound of the steel bar was characteristic and what we had been led to believe is true of most if not all infants. When it was suddenly sounded there was a sudden intake of the breath and an upward fling of the arms. On the second stimulation the lips began to pucker and tremble, on the third he broke into a crying fit, turned to one side and began to crawl away as rapidly as possible with head averted.

The result of this observation showing that the loud sound would produce an expression of extreme fear gave us hope that we might be able to use this stimulus for *bringing about a conditioned emotional response* just as the electric shock combined with the sight of the colored object brought about in the end the conditioned response of the finger just referred to. Our laboratory notes showing the progress of this test are most convincing.

Eleven months, 3 days old. (1) White rat suddenly taken from the basket and presented to Albert. He began to reach for rat with left hand. Just as his hand touched the animal the bar was struck immediately behind his head. The infant jumped violently and fell forward, burying his face in the mattress. He did not cry, however.

(2) Just as his right hand touched the rat the bar was again struck. Again the infant jumped violently, fell forward and began to whimper.

In order not to disturb the child too seriously no further tests were given for one week.

Eleven months, ten days old. (1) Rat presented suddenly without sound. There was steady fixation but no tendency at first to reach for it. The rat was then placed nearer, whereupon tentative reaching movements began with the right hand. When the rat nosed the infant's left hand the hand was immediately withdrawn. He started to reach for the head of the animal with the forefinger of his left hand but withdrew it suddenly before contact. It is thus seen that the two joint stimulations given last week were not without effect. He was tested with his blocks immediately afterwards to see if they shared in the process of conditioning. He began immediately to pick them up, dropping them and pounding them, etc. In the remainder of the tests the blocks were given frequently to quiet him and to test his general emotional state. They were always removed from sight when the process of conditioning was under way.

(2) Combined stimulation with rat and sound. Started, then fell over immediately to right side. No crying.

(3) Combined stimulation. Fell to right side and rested on hands with head turned from rat. No crying.

(4) Combined stimulation. Same reaction.

(5) Rat suddenly presented *alone*. Puckered face, whimpered and withdrew body sharply to left.

(6) Combined stimulation. Fell over immediately to right side and began to whimper.

(7) Combined stimulation. Started violently and cried, but did not fall over.

(8) Rat alone. *The instant the rat was shown the baby began to cry. Almost instantly he turned sharply to the left, fell over, raised himself on all fours and began to crawl away so rapidly that he was caught with difficulty before he reached the edge of the table.*

This was as convincing a case of a completly conditioned fear response as could have been theoretically pictured. It is not unlikely had the sound been of greater intensity and the child more delicately organized that one or two combined stimulations might have been sufficient to condition the emotion. We thus see how easily such conditioned fears may grow up in the home. A child that has gone to bed for years without a light with no fears may, through the loud slamming of doors or through a sudden loud clap of thunder, become conditioned to darkness. We can easily explain how it is that a sudden flash of lightning finds you all set and tense, often times with the hands over the ears, before the clap of thunder, which is the true stimulus to such action, appears. We can thus see further how it is that the sight of a nurse that constrains the movements of the youngster or dresses it badly may cause the infant to go into a rage, or how the momentary glimpse of a maiden's bonnet may produce the emotional reactions of love in her swain.

The experimental question arose as to whether Albert would be afraid henceforth only of rats, or whether the fear would be *transfered* to other animals and possibly to other objects. To answer this question Albert was brought back into the laboratory five days later and tested. Our laboratory notes again show the results most convincingly.

Eleven months, fifteen days old.

(1) Tested first with blocks. He reached readily for them, playing with them as usual. This shows that there has been no general *transfer* to the room, table, blocks, etc.

(2) Rat alone. Whimpered immediately, withdrew right hand and turned head and trunk away.

(3) Blocks again offered. Played readily with them, smiling and gurgling.

(4) Rat alone. Leaned over to the left side as far away from the rat as possible, then fell over, getting up on all fours and scurrying away as rapidly as possible.

(5) Blocks again offered. Reached immediately for them, smiling and laughing as before.

The above preliminary test shows that the conditioned response to the rat had carried over completely for the five days in which no tests were given. The question as to whether or not there is a *transfer* was next taken up.

(6) *Rabbit* alone. A rabbit was suddenly placed on the mattress in front of him. The reaction was pronounced. Negative responses began at once. He leaned as far away from the animal as possible, whimpered, then burst into tears. When the rabbit was placed in contact with him he buried his face in the mattress, then got up on all fours and crawled away, crying as he went. This was a most convincing test.

(7) The blocks were next given him, after an interval. He played with them as before. It was observed by four people that he played far more energetically with them than ever before. The blocks were raised high over his head and slammed down with a great deal of force.

(8) *Dog* alone. The dog did not produce as violent a reaction as the rabbit. The moment fixation of the eyes occurred the child shrank back and as the animal came nearer he attempted to get on all fours but did not cry at first. As soon as the dog passed out of his range of vision he became quiet. The dog was then made to approach the infant's head (he was lying down at the moment). Albert straightened up immediately, fell over to the opposite side and turned his head away. He then began to cry.

(9) Blocks were again presented. He began immediately to play with them.

(10) *Fur coat* (seal). Withdrew immediately to the left side and began to fret. Coat put close to him on the left side, he turned immediately, began to cry and tried to crawl away on all fours.

(11) *Cotton wool.* The wool was presented in a paper package. At the ends the cotton was not covered by the paper. It was placed first on his feet. He kicked it away but did not touch it with his hands. When his hand was laid on the wool he immediately withdrew it but did not show the shock that the animals or fur coat produced in him. He then began to play with the paper, avoiding contact with the wool itself. He finally, under the impulse of the manipulative instinct, lost some of his negativism to the wool.

(12) Just in play W. put his head down to see if Albert would play with his hair. Albert was completely negative. The two other observers did the same thing. He began immediately to play with their hair. A Santa Claus mask was then brought and presented to Albert. He was again pronouncedly negative, although on all previous occasions he had played with it.

We see that the conditioned fear to the rat, which was experimentally set up, transferred to many other objects. The transfer was immediate and without any additional experience in connection with these other objects. In these transferred emotional reactions we thus would find a reason for the widespread change in the personality of children and possibly even of adults once even a single strongly conditioned emotional reaction has been set up to any object or situation. It accounts for the many unreasoning fears and for a good deal of the sensitiveness of individuals to objects for which no adequate ground for such behavior can be offered in the past history of that individual. The importance of such a factor in shaping the life of the child needs no further emphasis from us.

At present we are engaged upon the study of methods by means of which such directly conditioned fear responses and their transfers may be removed. The importance of establishing methods for the removal of these undesirable reactions is apparent to all. That such conditioned reactions are present in the life of every child many parents can testify. We have repeatedly had children brought to us whose emotional life had been so warped and twisted by such factors that the formation of the stable habits by means of which the race must maintain itself was seriously interfered with. Some practical procedure in the control of these factors must be found if we are to care for those children in whom accidents of nurture have built up emotional reaction systems which, unless corrected, must inevitably bring them to grief. The report on this phase of our laboratory work is not yet completed.

The sceptic will be inclined to say that such things happen in the life of a child every day but that the child immediately puts them aside and soon forgets or outgrows such happenings. We have not the full experimental data to combat this view, but we have the evidence to show that in Albert at least both the original fear of the rat and the transferred emotional reactions remained after a period of thirty days in which no experiments were made. Furthermore, the latter were still called out by the same objects which called them out in the above test. Our view is that such happenings are permanently impressed upon the growing child. They remain not only as a part of his reaction system but also they tend to modify or prevent, by limiting the number of objects that he deals with, the formation of constructive habits. In other words, they modify his vocational future. When we consider that these conditioned emotional responses are being constantly set up in the growing child, not only in the realm of fear but in the realm of love and rage, and that they bring in their train a host of transferred responses, we begin to realize the importance of the preschool age of the child; we then wonder whether our home system which more or less allows our children to "just grow," like Topsy, until public school life begins, is not a pretty dangerous procedure.

We spend an enormous sum of money each year for the education of our youth in colleges and universities. When it is realized that the college, that institution for teaching the adolescent to become a man, is at present being regarded somewhat critically, and that the universities reach only an extremely small percentage of the population—namely that portion which intends to enter some specialty—it makes us wonder whether it would not be a valuable experiment for the government or other institutions to spend a small amount of our vast educational funds for teaching the infant how to become a child. When one realizes that probably more than the income from a million dollars is spent each year in the several marine biological institutions for the study of three lower forms—the sea urchin and its progeny, the coral, and the jelly fish—it seems not unreasonable to point out that it would not be bad economy to have one or more institutions where continuous researches might be made upon human progeny. An institution where the human infant can be studied from birth to at least three years of age would be one of the most profitable research investments that could be made at the present time. It would lead to an untold wealth of new scientific conclusions and to a practical and common sense set of data upon the psychological care of the infant.

AN INTRODUCTION TO SCIENTIFIC VAGARIES

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HOW to account for the "crank," and what to do with him, are questions that concern the general public as well as the specialist. Restrain him? He is irrepressible. Ignore him? That may be unwise for often he is half right, sometimes wholly so. He is always disturbing, and though always abnormal he is not always unworthy, and the genus is of such infinite variety that it can never grow stale. No, the crank cannot be ignored because he is always the embodiment of notions that influence others, sometimes in large numbers; he is a type. Much depends upon the point of view. Columbus was a wise and learned man to his simple minded sailors; to companions of like temper with himself he was a daring adventurer and a hero; to the incredulous savants he was a crank.

A really normal man is one whose mental, moral and physical qualities put him in what is called "normal" relation to the age and conditions of society in which he lives; he is in harmony with his environment and lives among his fellows without discord or friction.

One who continues to shape his conduct after the pattern of his predecessors, while failing to regard the advances that have been made; who will not ride in railroad cars or tolerate instrumental music in church; who declares that what was good enough for his ancestors is good enough for him, is "behind the times"; while he who is dissatisfied with prevailing views and customs, and chafes under the restraints which they impose upon him and consequently endeavors to better them, is either a crank or is "in advance of the age." If the latter is the case only the future can prove it; sometimes it does so—it may be soon, it may be centuries later.

As the "norm" would be in perfect equilibrium under the forces acting upon him from all sides, any excess or defect of qualities in an individual not thus normal, would leave him unbalanced. Just how far or in how many respects he may depart from the normal without being generally regarded as erratic, is indeterminate, but there are few persons who have not some crotchets, and those few we consider uninteresting and expect no especial achievement from them. It is only to the abnormal that we can look for any disturbance of an established order, whether for good or ill. Of these, some are a little out of line (but only a little) on many subjects; others are out of line on one

subject only, but very much out; they may be very right in general, and yet on some one topic their aberration may amount to mania. The crankiness that crops out in various fields of endeavor often exhibits surprising acumen, shrewdness, and insight, coupled with defects of reasoning no less remarkable. All this is trite, of course, to the alienist. Probably an expert in any profession encounters and could cite instances of such aberration related to his own profession, and these might all be classified. In any one branch of science they would make a formidable array, but it may be that they are all ultimately psychological. Sometimes the purely psychological aberration affects chiefly the actor himself, as in "New Thought" and such systems; and sometimes, when the performer is dishonest, it is meant to affect his victims, as in the Keely Motor and devices of that nature.

It is exhilarating to read the propaganda of strange cults among the announcements of Sunday services in the Saturday afternoon or Sunday morning newspapers of any large city. Employing various tricks of phraseology, especially alliteration, they fall readily in step with Mother Goose's rhymes or suggest the Mark Twain jingle:

> Punch, brothers, punch with care;
> League for the larger life.

Many of these "movements" are poorly disguised schemes for wheedling money from faddists—the old trick of "stealing the livery of the court of heaven to serve the devil in." While it is true that some projects once thought chimerical have been realized, and have thus justified their protagonists—at first villified as crack-brained, and then glorified as geniuses—the utterly fantastic character of other schemes shows an unquestionable wryness in the persons at work upon them. Education has been thought the cure for both moral and intellectual depravity, but the advocate of any of these absurdities would be classed as a "sport," a *lusus naturae,* which no amount of educating could convert into the norm. Why he so frequently and continually recurs is a mystery.

It is hard to tell which exhibits the greatest departure from the normal; the eager chaser after the will-o'-the-wisp, who is so wholly possessed by his idea that it becomes an obsession (that condition is abnormal even if he is sincere); the unscrupulous rogue who, by his plausibility, swindles his victims; or the admirers and victims themselves who, astute enough in general, are peculiarly susceptible to some particular form of deception, say scientific or religious, and who, along that line, are abnormally credulous and easily deceived—even in some instances pleased at being humbugged. The scientific mind is necessarily an open mind, and the over credulous imagine themselves especially scientific in their readiness to accept evidences of strange new truths. But they do not always properly weigh the evidence. An

array of testimony in the guise of facts, and of consequences that are unmistakable is often convincing before the evidence is known to be genuine, with no certainty that it means what they suppose, and least of all with any assured connection between the supposed cause and effect; and although "one swallow does not make a summer," a single fact is sometimes used to brace up a host of irresponsible and unfounded statements. There are well meaning people with a fair amount of intelligence, who will take keen interest in the pretensions of a mountebank if only he makes his claims startling or upsetting in character, and presses them with sufficient assurance and effrontery.

It is not the sincere worker whose efforts are based upon sound doctrine and real facts, and who works on in the face of discouragement, that we are considering, but the aberrant. Whatever may be his contention, his favorite method of establishing it is to challenge everything and everybody to refute it. If he is dishonest he wants notoriety and this will procure it for him, whether the challenge is accepted or ignored; if he is honest he is so far deluded that if his challenge is not accepted he is convinced that it is unanswerable, and if he is controverted he feels that, like Galileo and a noble army of predecessors, he is a martyr to the conservatism of the age which resents enlightenment. It is not always possible to take these disputants seriously, no matter how seriously they take themselves, neither is it always safe to dismiss their ideas as ridiculous, for many a wise man has been ridiculed and contemned by others less wise than himself; and we need not look upon a quotation from the Alice books as a sign of feeblemindedness.

In speaking of the Keely motor, an English engineer and critic makes a generalization upon the psychology of Americans that is pretty broad yet perhaps not without justification. He says:

> It is a peculiar psychological fact that among a people so energetic and hard headed as the Americans every imposture, depending for its success upon mystery, should find multitudes of believers. America is the home of Mormon, Christian Scientist, and a host of other sects, who each follow the leadership of a single person, it may be ignorant and impudent, or it may be of that much learning that maketh mad, but at least all agreeing in being mystics of the very first water. . . . American geese are always swans, and really Keely deserves a good deal of attention. (Henry Riddell, M. E., on "The Search for Perpetual Motion," in the Report and Proceedings of the Belfast Natural History and Philosophical Society, 1915-1916.)

Instead of indicating superstition, however, does not susceptibility to the unknown or the mysterious belong rather to the *unmatured* stage of a people, or such part of them as are not restrained by the conventions of those from whom they have become detached? To a people who, in some sense, are still pioneers, before they have grown stale, and while they retain a freshness of imagination to which they are not unwilling to give a loose rein; a condition which made Americans exuberant and bombastic, and gained for them a reputation that will require

a long time to live down. That would account for the free play of fantastic ideas among Australians as well as among Americans—ideas which usually find fertile soil in newly settled and rapidly developing countries.

Libraries serve as reservoirs into which erratic papers and pamphlets flow in streams. A typical collection of sixteen quasi-scientific pamphlets, bound together under the general title "Paradoxes," in the New York Public Library, illustrates the lengths to which such aberration may go. Several of the papers are notable, and one or two are notorious. Merely to scan the titles is enough to make one dizzy; they are not all old, some might be called recent. One or two will serve for illustration. No. 4 is:

> Six General Laws of Nature—(A New Idealism)—A COMPENDIUM—of—A Large Work Divinity and The Cosmos—Containing—The Positive Cause of Force and Matter, An Explanation On All The Physical Phenomena in the Actuality of The Universe, and an Attack on the Modern Scientists and Philosophers.—Solomon J. Silberstein—New York—1894.

To judge from the weightiness of this "Compendium" the "Large Work" would be crushing. Mr. Silberstein also has another on "The Existence of the Universe—The Causation of Its Origin, etc." which sets one wondering.

The papers are most varied and fantastic; one is a rhapsody of Man, God, Geography, Electricity, Sun, Moon, and Tides, and contains the announcement of "an extensive work entitled 'A New Bible' to explain in detail the scientific principles in the above topics"! In another the Rev. John Jasper is revived and the earth is proved to be a "stationary plane circle"; the Newtonian theory of gravitation is severely manhandled by several of the writers; and cosmic theories are proposed by some and overthrown by others; one especially affects odd words, and another article is made up wholly of epigrams and ejaculations of two or three words each.

An attendant in an asylum for the insane, speaking of the idosyncrasies of the patients, said that the form their hallucination would take "depended altogether on *the temperature of their minds.*" (He was himself apparently somewhat mixed on temper, temperature, and temperament.) Some of the writers of these papers rival the projector in the Grand Academy of Lagado, spending his labors on a project to extract sunbeams from cucumbers.

During the Middle Ages superstition was rife in science, and vagaries abounded; in the eighteenth century a great clarifying was in progress, and by the beginning of the nineteenth extreme ideas of science were thought to have reached their acme of extravagance in seven different forms corresponding, perhaps, to the seven wonders of the world, and called the "Seven Follies of Science." This designation is itself a survival of a tendency as old as counting, to recognize some

peculiar potency in a number like three or seven (particularly seven) as magical or sacred; and this tendency may be only another instance of the very peculiarities we are setting out to consider.

The late John Phin, in "The Seven Follies of Science," distinguishes properly between fraud and honest effort to discover and utilize the secrets of nature. In so discriminating he, with others, rejects astrology and magic because they are frauds, and gives as the generally accepted list of "Follies":

1. The quadrature of the circle; or as it is called familiarly, squaring the circle.
2. The duplication of the cube.
3. The trisection of an angle.
4. Perpetual motion.
5. The transmutation of the metals.
6. The fixation of mercury.
7. The elixir of life.

I. D'Israeli, in "Curiosities of Literature," enumerates the "Six Follies of Science," omitting Nos. 3, 5, 6, and 7 of the above list, and including:

4. The Philosophical (or Philosopher's) Stone.
5. Magic.
6. Judicial Astrology.

Nos. 1, 2, and 3 above are purely mathematical and do not belong in a list that is limited to the physical sciences. The others are things to be achieved or produced by experimental processes or search and in that class come also,

8. The Universal Solvent; and 9, The Fountain of Youth. This, indeed, is only a variant of No. 7, but it has been hardly less alluring than the others.

In their relation to the existing state of knowledge these have all stood, in their day, as rational topics of inquiry, and therefore as legitimate questions to which a conclusive answer might be expected. For this reason they ought not to be called follies, for even if they may now be regarded as such it was not always so, and with as good reason we might regard as folly almost any novelty in the development of science. So we call them fallacies or foibles when we are not dealing with outright fraud; in that case we have "perversion" of science. In most instances the great difficulty has been to determine the line between honesty and deceit. Even frauds would not be excluded from foibles in all cases, for it is impossible to know how far astrologers and soothsayers came to believe in their own schemes of forecasting and divining. Charlatans and fakers have possibly been self deceived, especially in religion. Certainly some weather predicters have believed in their scheme of forecasting, even if they did not believe in themselves.

It will be seen that in the above lists, some of the subjects that have been dismissed as chimerical have been capable of reaching a phase such as science now approves, and various chimeras, once laughed out of court, have returned to make good their claim to acceptance and to serve us. As notable examples that have been realized we have aviation, self propelled vehicles, and apparently the transmutation of metals. Geographical vagaries have sometimes been of wide scope and long sustained interest as, for example, the myth of Atlantis, the Northwest Passage, the Fountain of Youth, El Dorado, Symmes' Theory of Concentric Spheres, and still others. In 1492 the spherical form of the earth was a foible of Columbus.

An announcement of any startling achievement for which the public has not been prepared by gradual approach, is almost certain to encounter incredulity. Today the X-rays are commonplace, yet not only laymen but professional physicists were skeptical of them when the first announcements of them were received in this country. A final solution of the great problems of physics and chemistry, such as gravity, heat, electricity, radiation, etc., involves the ultimate nature of matter—itself the greatest problem of them all—and while the search for its solution continues vagaries will certainly come and perhaps go. No innovation that appears to be subversive of established ideas can acquire a standing without overcoming opposition in various forms, and one of the earliest and most effective forms that it has to encounter is ridicule or satire. But it has happened more than once that the chief fault with the innovation was that it was premature; and while in such case it needs great vitality to survive the ridicule with which it is met, if it is really true it is likely to reappear after an eclipse. Does it necessarily follow, however, that if it reappears it is really true? That has occurred with some systems of divining that have been scouted by orthodox scientists. Nevertheless, doctrines that have stood as sound science in their day, reached maturity and flourished, which died and were buried, may yet be awaiting resurrection. Some of them, if they were now being promulgated for the first time, would be either ignored or laughed at in the light of modern knowledge which would show their fallacy. Again, apparently defunct notions have been resuscitated and revamped and brought into harmony with present day knowledge and practice, have been shorn of excrescences that deformed them and stripped of dress that disfigured them; and in consequence, doctrines that had been rather fantastic have received a real scientific character, and truths that had fallen into disrepute may have been rescued. This seems to be the case with physiognomy. Some vagaries are veritable Banquo's ghosts and will not down. Insuppressible and irrepressible, with these revival takes the place of survival, and they return again and again to plague one, or else to establish finally an indisputable right to live. Reversing the usual order, the follies of one generation

have sometimes become the wisdom of the next. But it is not easy to escape contamination with bad associates, and upon any recurrence of old vagaries, even if they come bearing the promise of reform, they are apt to be put in the same class with new ones. Of these we have a superabundance in the shape of New Thought, Faith Healing, The Power of Will, etc., crowding the advertising columns of newspapers and magazines. What with short cuts to success, and marvelous methods of increasing one's power in all lines of endeavor, along with the ability to read character at sight, it would seem as if there were no excuse for anybody with moderate ability to stop short of the topmost rung in the ladder of Fortune or indeed to rest with only moderate ability. The situation is hit off well in an editorial of a current periodical:

> Life as it is lived by the rest of us must seem like loafing to those who have had their memories trained so that they can get the telephone book by heart in an evening, who have studied the science of physiognomy until they can place a passing stranger at a glance, and who have mastered the secrets of will power to such an extent that it is folly to dispute their purposes. Existence must appear a strangely pallid affair to you when there is no occasion to which you are not equal and when you have reduced the problems of every day to a series of logarithms, and locked them fast in an unshakable memory. (The Globe and Commercial Advertiser, New York, Nov. 12. 1919.)

While some of the old "Follies" persist, the progress of science has brought new ones to the fore and has focused attention upon wonders of a kind that did not—could not—enter the minds of the ancients. Whether the elixir of life, the fountain of youth, or the universal solvent has passed out of question or not, perpetual motion still engages the attention of inventors. The fact is, the thing that has become known and established has ceased to inspire the researcher. He is ready to pass that on to the utilizer, while his imagination revels in chimeras. A world consisting entirely of known facts would be as fatal to imagination as an arid world to vegetation.

THE GOVERNMENT LABORATORY AND INDUSTRIAL RESEARCH[1]

By GEORGE K. BURGESS, Sc. D.

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YOUR Chairman has asked for a contribution to this symposium on Research setting forth the relations of the Government Laboratory to Industrial Research. In the short time available, you will not expect more than the briefest outline of the attitude of one or more typical laboratories toward the encouragement and development of research in industry, the most concise possible of statements describing how a government laboratory functions in relation to industrial research problems, and a bare mention of but a few of them.

There has been a great deal written recently concerning the various aspects of industrial research and especially the rôle that is being played, or should be played, by each of the various types of organization, such as the Engineering Society, the university, the independent research organization, the Government, and industry itself; and the discussion often has centered about the cooperative aspects of research as between two or more of these parties.

It is generally conceded by representatives of industry that industrial research has for its immediate object the increase of profits, and consequently the brunt of the cost of maintenance should be borne by industry, which should also itself carry out at least the greater part of the research work required. There is a very great divergence of appreciation of the need and value of research in the various industries, and the practices and methods also vary greatly.

It is generally conceded that the rôle of the university is to train men and increase our store of knowledge; many think useful cooperative arrangements in research may be made between the university and industry, and many illustrations are available.

It is not the purpose of this paper to go into a philosophical or academic discussion of what part the government laboratory should play on the stage of industrial research but rather, accepting the facts and tendencies as they are, to state briefly, if inadequately, what two of the government bureaus are trying to do to encourage and help industry through research in science, engineering and technology.

[1] American Society for Steel Treating, September 23, 1921, Annual Convention at Indianapolis.

It has been well said: "All research is in the public interest, and that from the public viewpoint the sole difference between abstract and applied science is one of degree and not of fact; that the important point is increased research activity irrespective of where or by what means it is carried on."

If, therefore, the public has an interest in and derives benefit from industrial, scientific research, it is both fitting and fair for the public, through the agency of the Government Laboratories, to both participate in and help support such research.

It also follows that there should be established and maintained the closest relations between the representatives of industry, on the one hand, and of the government laboratories, on the other. This intimate contact should evidently not be limited to scientific and technical staffs of the industrial and government laboratories, but should embrace also the directors of policy in industry and government.

There is another and most important characteristic of the government laboratory in its relation to this question of industrial research, one that has been often mentioned, namely, the desirability in many cases of having the work done, in whole or in part, by an impartial body representing the public and on whose results will be impressed the stamp of authority; as in cases in which if one or the other party, as producer and consumer, either alone or together, published the results, they would not, however well executed, carry the desired weight.

Again, one should not lose sight of the fact that our government is the largest business organization in the country, the most important buyer and also maintains several types of industrial or manufacturing plant of a highly technical nature. So the government itself, in the conduct of its business, is a party vitally interested in the progress of industrial research, economies in buying, and standardization of products. The results obtained in its laboratories on its own problems are freely given to industry. The rôle of the Bureau of Standards has been preeminent in research for the government and many of its activities in the field of industrial research have been started for the purpose of meeting government needs for information relating to improvements in manufacturing processes, standardization and the formulation of specifications. As illustrations, may be cited the investigations relating to cement, concrete, paper, leather, rubber and textiles, for which small manufacturing plants have been installed.

It is often maintained there are three essential steps in many branches of industrial research, particularly as related to new processes; first, the laboratory investigation; second, the development on a small manufacturing scale; and last, full scale production, all of which require experimentation. The government bureau may be and often is associated with all three of these stages.

What now do we find to be the relation of the government laboratory to the industries of the country?

We may perhaps best approach the subject by asking of what aid can the government laboratory be to the American Society for Steel Treating, to its members individually and to the industries it represents?

There are two government bureaus the work of which is most nearly related to the scope of interests covered by this society, namely, the Bureau of Mines and of Standards. Each of these bureaus is vitally concerned with promoting the welfare of the nation in matters relating to their respective fields. They may be considered as great technical service bureaus to which the engineering, scientific and technical interests of the country may apply for help in solving many of the underlying problems of general interest in mining, technology, engineering, physical and chemical science, and in standardization, on all of which progress in industry is based.

From the viewpoint of cooperation with industry, how do these two institutions function with respect to industrial research, which we may define as research with an avowed utilitarian motive?

Let us consider first the Bureau of Mines. In the annual report of the director for the year ending June 30, 1920, appears this statement:

> During the past few years the bureau has been building up investigative work with outside cooperating agencies in a manner unique among Federal bureaus. The detailed agreements entered into differ among themselves, but the fundamentals are these:
>
> 1. Some state, or university, private or semi-private organization has problems in mining or metallurgy the solution of which would benefit itself and the public.
>
> 2. These outside agencies agree to pay part or all of the cost, both in personnel and materials, of the investigation, which is to be carried on under the direction of, and according to, the methods of the Bureau of Mines.
>
> 3. The Bureau of Mines retains the right to make public and print the results of all such investigations.
>
> So successful has this method of solving problems been that at present the bureau has cooperative agreements with State agencies in 11 states, with 12 different universities, and with 19 private and semi-private agencies. And the total amount of money being spent by the outside agencies on these cooperative agreements, mostly under the direction of the bureau, has amounted to approximately half a million dollars during the present fiscal year. In addition, a number of representative concerns in leading mining and metallurgical industries have appropriated money to be spent under the direction of the Bureau of Mines in production of educational motion pictures illustrating various mining and metallurgical industries. The bureau has found that these films are in great demand by the public, and that they have materially assisted the wide dissemination of information concerning the industries.

As in the case of agriculture, the mining industry is scattered over a wide geographical area and the problems to be solved are often local;

therefore it was but natural for the Bureau of Mines to follow the practice of the Department of Agriculture in establishing experiment stations at suitably located points for the study of problems relating to the mining industry.

The Bureau of Mines is also charged with the government work on fuels—a subject of no little interest to the membership of this society—which include, of course, coal and petroleum products of widely diversified types and situated in many areas. In its study of fuel problems, the Bureau of Mines has carried on both the field and station type of investigation but has also been able to concentrate in one or more central laboratories much of its fundamental research work.

In problems relating to process metallurgy, such as the recovering of the various metals from their ores, much the same procedure has, of necessity, been followed as for the mining operations, namely work at outlying stations. In both mining and metallurgical investigations it is the custom to cooperate on an intimate and intensive scale with existing industrial plants, to the very great benefit in the increase of our knowledge and improvement of the processes concerned, to say nothing of the evident economies of such methods of cooperative investigation. With the experience gained by this Bureau in successfully overcoming the difficulties in one region available for new problems as they may arise elsewhere, there is evidently also elimination of much wasted effort in trying out a new or modified metallurgical process.

In its investigations relating to mineral technology and elimination of waste in metallurgical operations, this Bureau is doing much of direct interest to this society, such as smoke and fume abatement, health conditions in shops, furnace design and operation, metallurgical refractories, and the making of alloy steels, a long list, the consideration of which here would take us far afield.

Turning now to the Bureau of Standards, we may note certain differences in methods and procedure as compared with the Bureau of Mines. We have seen how the latter bureau maintains a large number of widely scattered units or stations. In contrast to this decentralized practice, the Bureau of Standards has practically all its work concentrated in a group of laboratories at Washington although it has maintained an important station at Pittsburgh mainly for engineering work on structural materials which station, however, is being moved to Washington; there are also a few small detached stations for cement and chemical testing.

Again, the Bureau of Standards has followed less generally than the Bureau of Mines the practice of entering into formal cooperative agreements with States, and other public or private bodies. We have usually adopted the less formal, but nevertheless effective, practice, in our relations with industry, of orienting and organizing our work through the instrumentality of committees representing industry.

It has been said committees do no work and therefore are unnecessary, but a moment's consideration will show that in many ways a well organized committee is most valuable, if not indispensable, in laying down principles and suggesting policies, resulting from the united experience of all its members. The Bureau of Standards finds in many lines of its work relating to industrial research that the committee method of outlining the problem is the only feasible one. There is established a mutual confidence among all interested parties so essential in attaining the maximum output with minimum risk of misdirected effort.

As a text defining the Bureau's relation to industry, let us quote again from Mr. A. W. Berresford in his presidential address before the American Institute of Electrical Engineers:

> I conceive it to be the prime duty of the industry, first to agree on what shall be the scope of the Bureau; second, to educate the Bureau in its conditions; and third, by demanding that its interests be heeded, to secure adequate support of the Bureau.

At the outset, it may be laid down as axiomatic that the director of the bureau has never considered undertaking any problem in research relating to industry without first consulting representatives of that industry, either as a group through some organized body speaking for the industry or by consulting with men of authority in the industry. Many are the illustrations of this practice; for example, there has been for years a committee appointed by various bodies interested in nonferrous metals, known as the "Committee Advisory to the Bureau of Standards on Non-Ferrous Metals," or for short, the non-ferrous committee, which meets at the bureau twice a year. All the work on this subject is gone over before and during its execution, so that the nonferrous metal investigations of the bureau have not only the endorsement of the industry but the industry itself formulates the program. If progress in this domain has been less rapid and extensive than we should like, may we then say that, although the first two of Mr. Berresford's conditions have been met, the third is lacking?

The work on railroad materials has, less formally, been largely mapped out as a result of meetings held at the bureau of representative railroad groups. Sometimes a specific problem that appeals to the bureau may be presented by some railroad together with a manufacturer; such was our work on rails from different ingot types, and the investigation now being conducted on Titanium treated rails; or again a manufacturer's association as that of Chilled Iron Car Wheels may ask the bureau to cooperate in carrying out an investigation—just completed—on thermal stresses in chilled iron car wheels as related to design and braking; or it may be an unorganized group, as that of the steel wheel manufacturers, asking for and getting a similar investigation. Nor should there be forgotten the bureau's activities in the realm

of engineering materials in its relation to the numerous committees of the American Society for Testing Materials, which committees are fairly representative of both the consuming and producing elements of their respective industries and represent as well the engineering public. I suppose the list of direct or implied requests for work by this engineering body alone would reach the size of a substantial volume.

Another problem and another type of organization. Whether he realizes it or not, every one in this country is vitally concerned in the limitations set for sulphur and phosphorus content in various grades of steel. If these limits are fixed too rigidly the cost of living rises, if too loosely, the life hazard of all of us is increased. This problem was brought formally to the bureau's attention by two bodies, one representing the government, the other the engineering fraternity; or by the Railroad Administration and the Society for Testing Materials. A joint committee was formed representing the government departments, the specification making bodies, and the manufacturers. The testing and research is carried out in the government laboratories at Watertown, Annapolis and Washington, and the steel is specially produced for the investigation by the manufacturers under the oversight of the committee. A unique feature of the conduct of this investigation is that there is not a two sided table with manufacturers on one side and the users on the other—but it is a round table affair with each man responsible for endorsing each stage of the program so that no member can later say, why did you not do this or that?

The bureau's investigations on electrolysis as related to public service companies and cities are being organized on a somewhat different but nevertheless highly satisfactory basis, in which all interested parties are represented and the program put up to the bureau by them.

Hardly a day passes that there is not one, sometimes several, formal or informal conferences at the bureau by groups representative of industry who are interested in having the bureau undertake problems of research fundamental to their industry, and at those conferences the work to be done is usually mapped out, at least on general lines and often in great detail.

At the present time much attention is being given to problems relating to the elimination of industrial wastes. The possibilites of progress in this field are of unlimited extent. In a sense, of course, all industrial research from which beneficial results are obtained lead inevitably to the equivalent of elimination of waste by conservation and better utilization of materials, improved quality of products, recovery of by-products, increased efficiency of performance, or discovery of new processes and products. There are, however, many instances in industry in which the waste, as such, is evident and manifestly preventable, and it is to problems dealing with these classes of waste to which

I refer. As examples we may mention the enormous losses caused by corrosion, inefficient furnace operations, excessive use of manganese, and other preventable losses of material and energy in steel manufacturing operations.

Another field of industrial research, and one that will grow in importance, relates to our foreign trade, particularly the specification and testing of materials for export. The establishment and maintenance of standards in this wider competitive field will require much more experimental research than might be thought necessary by one who gives the matter but hasty attention. In fact in the realm of standardization and specifications, as those of you know who may be familiar with some phases of this subject, you never get far in writing a specification before you enter the unknown, and the way can be cleared only by further experimental investigation.

We might cite many other types of problem related to industrial research on which the Bureau of Standards is now working or is qualified to assist in solving in collaboration with industry, but I trust what has preceded has given you a better idea than you had before of the relation of the Bureau to industry and the readiness at all times on its part to participate with industry in the solution of those problems of general interest coming within its scope. The same is, of course, equally true of the Bureau of Mines.

Before closing, I would like to mention one other type of activity at the Bureau—still in an undeveloped state—which gives promise of being of considerable value to industry. I refer to the practice started about two years ago of an industry sending men to work at the bureau on problems that industry is interested in having solved and for which the equipment and atmosphere of the bureau may be particularly suited. This practice was instituted by the bureau largely in self-defense at a time when manufacturers were drawing men from it in alarming numbers and it was also coincident with the reduction of the bureau's funds. We call these men Research Associates or Assistants, and at the present time there are twenty, six of whom are working on metallurgical problems, and the others on problems relating to hollow tile, terra cotta, visibility, lime, gypsum, plasticity of fats, cement, and the constants of ammonia. There are great possibilities in the extension of this system under which men are trained as well as problems solved, and the benefits to industry are self-evident.

Much might be said of the educational advantages of the government laboratory in training men for research positions in industry. The Bureaus of Mines and Standards often have been severely crippled by losing men to industry. It is not in general to the advantage of industry to so cripple an organization working for the benefit of industry.

A last word—and only a word—as to the cost of research, indus-

trial or any other. It is trite to say it is expensive, so is life insurance; but it is far more costly not to support research adequately, just as it is not to make provision for future contingencies. It has been said that such government laboratories as the Bureaus of Standards and Mines are luxuries we can easily dispense with; yes, just as the farmer's seed and fertilizer can be dispensed with to his ruin. What does it cost per capita for the Bureau of Standards or the Bureau of Mines? Almost exactly a cent apiece for each inhabitant of this country, which if I were not a member of the staff, I would characterize as dirt cheap, the price of the tax on one ten cent "movie" ticket.

The American Society for Steel Treating is concerned with many problems, some of them of great intricacy, involving not only the perfection of practice in the subject of heat treating but dependent also upon the new facts to be discovered relating to the properties of the various types of steel and the characteristics of many auxiliaries such as fuels, refractories, pyrometers, quenching media, furnace control and design; problems relating to geometry and mass of heating and cooling objects, and many others.

We, at the Standards Bureau, would be glad to see formed within this society, a committee advisory to the Bureau on Heat Treatment of Steel, which would enable us to keep in touch with each other so that the bureau's efforts in this field of investigation would be constantly in harmony with the most progressive minds in the country interested in furthering progress in this subject.

Finally, I want to make a special plea for scientific research in industry at this time. We have been witnessing, during this period of depression, the cutting down and even entire wiping out of many research departments. How many times have we all heard the argument: in times of prosperity we have not the time and do not need research, and in hard times we cannot afford it? In my opinion, the wise Board of Directors is the one which stimulates research in hard times even if it has to borrow money to do so. Competition will be keener than ever as prosperity returns and the company which has in the meantime sharpened its tools by increasing its research facilities will score in the long run. There is no greater economic waste than wrecking a going research group.

AMERICA'S FIRST AGRICULTURAL SCHOOL

By Dr. NEIL E. STEVENS

U. S. DEPARTMENT OF AGRICULTURE

THE establishment, a century ago, of "an institution destined to prepare youth by a scientific education to become skillful farmers and mechanics" is in itself notable. As the Gardiner Lyceum was not only our first agricultural school, but the first institution to receive a state appropriation for agricultural instruction, its foundation may almost be said to mark an epoch. The importance of agricultural schools and colleges in our educational system renders of present interest a brief sketch of this pioneer institution, which emphasized the practical value of science, and introduced an elective system, student self government and winter short courses.

The idea of such a school originated with Robert Hallowell Gardiner, who was a member of its board of trustees and its chief benefactor. Of this remarkable man, pioneer in many lines and promoter of everything that seemed for the good of the community which now bears his name, little need be said. Sympathetic biographical sketches are avilable (5) and his work is mentioned in several histories of Gardiner, Maine (7). His part in the origin of the Lyceum is, however, of direct interest and is told in the manuscript autobiographical notes which he prepared some years before his death and which are now in the possession of his descendants, who have courteously made them available to the writer.

In beginning his account of the foundation of the Lyceum, Gardiner states that he had frequently been impressed by the fact that skilled workmen, such as surveyors and millwrights were

> wholly ignorant of the principles upon which their arts depend, so that when anything occurred out of the common routine, I found them utterly at a loss how to proceed. Our farmers were still less intelligent.
>
> After reflecting much upon this subject, I became impressed with the belief that an institution might be established which would put the acquisition of so much science as was requisite to make skillful farmers, millwrights, and other mechanics, within the reach of all who wished to follow these branches of business. I communicated these views to a number of gentlemen of practical intelligence who highly approved them, as was shown by their subsequently sending their sons to the Lyceum when it was established. Wishing the co-operation of my fellow citizens, I called a meeting and proposed the subject, which produced a hearty response.
>
> I proposed to give as an endowment 312 acres of land fronting on Kennebec River, and valued at $3,744.00 to which I subsequently added 122 acres adjoining, making a total of 434 acres valued at $5,208.00. They proposed to erect the building to which I only contributed $100.00.

The building referred to was a substantial two-story stone structure, and its erection by subscription is evidence of real interest in technical education in that community. In the development of such a sentiment the work of Dr. Benjamin Vaughn (3) in making available through publication in this country European work on agriculture, notably the now little known "Rural Socrates" (1800) and some extracts from Buffon's works, in urging the importance of experimental study of agricultural problems, and in the establishment of agricultural societies, must have played a large part.

The grounds and building for the new school being thus assured the state legislature was petitioned for an act of incorporation and for assistance. A portion of this petition is here quoted for the statement it gives of the purposes of the Gardiner Lyceum.

> The petition of the subscribers represents that a donation has been offered of land lying on Kennebeck River, estimated at $4,000.00 for the purpose of establishing . . . a school for teaching mathematics, mechanics, navigation and those branches of natural philosophy and chemistry which are calculated to make scientific farmers and skillful mechanics.
>
> And whereas it is an object of very great importance to any state . . . that its citizens should possess an education adapted to make them skillful and able to improve the advantages which nature had so lavishly bestowed upon them, and whereas the State of Maine . . . has hitherto omitted to make provisions for giving instruction to her seamen, her mechanics, and her farmers, upon whom the wealth and prosperity of the State mainly depend . . .
>
> They would therefore pray your honorable bodies to incorporate a school for the above purposes, with a body of seven Trustees with the usual powers and privileges, to be called the "Gardiner Lyceum" and to grant such aid as will enable the Trustees to bring the school into immediate usefulness. Signed by R. H. Gardiner and 53 others.

In response to this petition the Maine legislature passed what is apparently the first recognition, by an American legislative body, of a distinctively agricultural school.

> Private acts of the State of Maine, Chapter CVIII.
>
> AN ACT to incorporate the Trustees of the Gardiner Lyceum.
>
> Sec. 1. *Be it enacted by the Senate and House of Representatives, in Legislature* assembled, That an institution, designed to prepare youth by a scientific education to become skillful farmers and mechanics, be established in the town of Gardiner, to be called the Gardiner Lyceum; and that Robert Hallowell Gardiner, Peter Grant, Sanford Kingsberry, Frederick Allen, John Stone, and Edward Swan, Esquires, be and they are hereby incorporated into a body politic, by the name of the trustees of the Gardiner Lyceum; . . .
>
> (This act passed January 30, 1822).

The Gardiner autobiography states that the name "had been chosen to distinguish the institution as distinct from a high school or college" and further that "Mr. Allen almost immediately resigned and Mr. Evans, who was very efficient in carrying out the objects of the institution was elected in his place".

The next step was the publication, in 1822, of an "Address to the Public" from the trustees of the Gardiner Lyceum. This address, which was prepared by Mr. Gardiner and signed by him in the name of the trustees, stresses the importance of a knowledge of science in practical affairs, and outlines the objects of the institution, as indicated by the following quotations:

> The practical utility of science cannot be doubted, in an age where its investigations have produced such astonishing improvements as in the present. There is scarcely an art, which has not directly or indirectly received from it important services, for science must necessarily be the foundation of every art.
>
> With a view to furnish to farmers and mechanics the education here represented as so useful, the Gardiner Lyceum has been established; and the course of study will be arranged with particular reference to the wants of those classes, for whose particular benefit it was designed. As soon as a suitable apparatus can be provided, lectures will be given upon the sciences there taught; and the application of those sciences to the arts will be illustrated as fully as the nature of lectures will admit.

Gardiner states in his autobiography that, "Copies of the address were sent among others to the two ex-presidents, Adams and Jefferson, from both of whom I received civil answers approving the plan". Thus, even in small ways, did these two great Americans promote the cause of education.

The address referred to announces the opening of the school early in January, 1823, and the appointment of Mr. Benjamin Hale, a tutor in Bowdoin College, as principal and lecturer in natural philosophy. Of him the Gardiner autobiography says with apparent fairness:

> Mr. Hale was admirably adapted to the situation. He was a man of great insight into character, and with a strong disposition to break through established routine when change offered improvement, and therefore entered warmly into a plan which though novel, promised essential benefit to an important class in the community. He had the power of gaining the confidence and commanding the respect of young persons intrusted to his charge, for while he was earnest to give them high motives of action, he thought it better not to notice and punish trifling misdemeanors arising rather from boyishness than from bad disposition.

Mr. Hale's inaugural address, which was published by the trustees, follows Mr. Gardiner's publication in emphasizing the practical importance of science and states the object of the Lyceum in these words:

> In exhibiting, as we have endeavored briefly to do, the connexion of science with the useful arts, and showing the importance of the former as the foundation of the latter, we have given you in part the views, which led to establishment of the Gardiner Lyceum. It is the object of this institution to give instruction in those branches which are most intimately connected with the arts, and to teach them as the foundation of the arts. In this respect we believe its design to be original.
>
> But it is plain that to practical men science must be taught in a practical manner. We are taught this by the frequent failures of men who are not deficient in the general principles of science, but who are unacquainted with the particular science of the arts.

Under Hale's enthusiastic leadership the institution throve. In January, 1823, an appropriation of one thousand dollars and the tax on the Gardiner bank amounting to another thousand was secured from the state legislature. The catalogue published in November, 1823, shows that there were twenty students, the next fall there were fifty-three and in February, 1828, a committee of the Maine legislature reported that,

> Since the Institution commenced its operations, the number of students who have been instructed there, for longer or shorter periods of time, is one hundred and ninety-one. Many of these have completed the whole term of three years . . . Several have remained for shorter periods having in view the attainment of but one particular science, such as surveying, mechanics, navigation, chemistry, . . .

The catalogue for 1823 announces (p. 9) an elective system which must have been as much of an innovation as the school itself.

> It will be seen at once, from the remarks above made, that the course which will be pursued cannot be minutely detailed as it must often be subject to variations from the necessities of students, arising from the nature of the object they have in view and the pursuit for which they wish to be qualified. These objects and destined pursuits of the students will ever be attended to, and no one will be obliged to study that, which will not be of material service to him . . . Where there are several who are under the necessity of leaving the common course, and their studies take the same direction, they will form a class, and if a suitable text book can be found, recitations will be had as usual. But in most cases, particular studies, such as the application of chemistry to the individual Arts, will be pursued by one or two only, and suitable books for recitation can rarely be had. Such students must pursue such a course of reading as will be pointed out to them, and will be assisted by frequent Examinations and Explanations, and will have when necessary the liberty of privately experimenting.

The announcements in the catalogue for 1824 were even more startling and include the inauguration of winter short courses for those unable to attend the full session, with instruction in surveying, navigation, architecture, and chemistry; and the development of a plan of student self government not unlike that in use in some colleges to-day. The catalogue for 1824 concludes with this optimistic remark:

> We hope that the time is not far distant, when it shall be as common for farmers and artists, to prepare themselves for their business by a suitable and thorough education as for lawyers and physicians.

In August, 1827, Mr. Hale resigned to become professor of chemistry at Dartmouth. Of this the Gardiner autobiography says:

> His loss was irreparable. He had identified himself with the institution, and associated its success with his own reputation.

In January, 1828, there appeared the first number of the *New England Farmer's and Mechanic's Journal*, this monthly which was published in Gardiner, continued for ten numbers, and contained original and quoted articles arranged under three headings, Mechanics,

Agriculture and Miscellaneous. Under the first head were included descriptions of such machines as the "Bliss moveable hay press" and "Lane's patent Corn-Sheller"; under the second were discussed "Economy in fodder" and "Preservation of Potatoes" and similar subjects; while the third division included such timely matter as "Method of making Transparent Soap" and "Blacking-Balls for shoes." The cover of the journal bears the inscription,

Conducted by E. Holmes, M. D., Professor of Chemistry, Natural History and Agriculture in Gardiner Lyceum.

Ezekiel Holmes, a graduate of Brown in 1821, and of Bowdoin Medical School in 1824, was appointed to the faculty of the Gardiner Lyceum in the fall of 1824. Whatever his influence in that school, and the Gardiner autobiography indicates that it was not great, his connection with it was apparently effective in directing his attention from medicine to agriculture to the great benefit of agriculture in the State of Maine. He was for over thirty years editor of the *Maine Farmer*, the first secretary of the state board of agriculture, and of the state agricultural society and the

last public act of his life was that of securing from the legislature in February, 1865—but a week before his death—an act which established the State College of Agriculture and Mechanic Arts as a separate and independent institution. (4:44-46).

After 1831 state aid for the lyceum was withdrawn, and at this time Mr. Gardiner himself recommended that the school be closed, "but the feeling of the citizens was so strong for its continuance" that an attempt was made to carry on the work. The nature of the institution, however, became gradually changed until the studies were practically those of the other academies throughout the state. Whereas in 1824 the course of study included no languages except English, and featured chemistry, natural philosophy, agricultural chemistry, mathematics and navigation; fifteeen years later (catalogue of 1839) the course of study included Greek, Latin, French and Spanish, with science occupying an inconspicuous place. In 1839 a "Female Department" was opened in the lyceum. In 1848 it was reorganized as an academy, and in 1857 the building, which was later (1869) destroyed by fire, was sold to the city of Gardiner and occupied as a high school. (7).

The question naturally arises why an institution so broadly planned and so successfully started should have decayed so quickly. For its continuation as a popular institution state aid was necessary and this could not be secured after 1831 for reasons set forth by Gardiner in his autobiography.

The plan of the school required considerable funds for its support, and from the general approbation with which the plan was received by the public, it was supposed that these funds would be readily granted by the Legis-

lature. It had however been but a short time in operation before jealousies were excited, and opposition grew up in various quarters. The Academies found their scholars attracted to the superior education at the Lyceum, and the Colleges believed that they would lose scholars who could dispense with the classics and be satisfied with a more practical knowledge, attained with a less amount of time and money.

Then came into operation the religious prejudice. All the higher institutions of learning were under the patronage of some particular denomination. They therefore combined against an institution which claimed no sectarian support . . . . . [and] it was evident that no further aid could be expected from the State.

The work begun by the Gardiner Lyceum has not been neglected, however. Robert Hallowell Gardiner concludes his autobiographical record of the lyceum with a reference to the establishment of the Lawrence Scientific School and to the fact that many

colleges have modified their laws . . . a higher practical education is therefore now afforded to those who desire it than could be attained at the Lyceum, which was only designed to give needful instruction to the laboring mechanic without raising him out of his position.

The very years those words were written (probably 1859-1861) there was being pressed in Congress an act which was to establish in every state institutions for the very purpose and along much the same lines as the Gardiner Lyceum. Indeed, so wholly in sympathy with the aims of the lyceum was the author of that act, Justin S. Morrill, that it is difficult to avoid the belief that he knew of the Gardiner institution. Morrill was a young clerk in Portland, then the capital of Maine, from 1828 to 1831, years in which its claims were being actively pressed before the legislature. May not the future legislator then have followed with interest the discussions upon the Gardiner Lyceum?

STATE AID

One thousand dollars as the annual expenditure of a state for agricultural education seems small, but a century ago, forty years before the passage of the Morrill Act by Congress, such a step was evidence of unusual progressiveness and interest. This appropriation, first made in 1823, and renewed in 1825 for three years, and again in 1828 for three years, was apparently the first allotment of public funds for agricultural education in the United States. When it is remembered that this enactment was made by the legislature of a new and sparsely settled state, for an institution wholly new in design, the wonder is not that the appropriation was so small and continued for only seven years, but that it was made at all.

That so advanced a position was taken by Maine legislatures at this early date is due to several influences. The state was strongly committed to a policy of public support of education by the recently adopted constitution. In fact the portion of that constitution which deals with education and authorizes state support of academies and col-

leges (Article VIII) had been prepared only a few years before by Thomas Jefferson, founder and even then the acknowledged leader of the party to which a large majority of the legislature belonged. Moreover, Maine was fortunate in her early years in having a succession of able and progressive governors who were interested in education.

The first governor, William King, was, as a member of the constitutional convention, active in having Article VIII included in the constitution, and later (2) vouched for the fact that it was in substance prepared by ex-president Jefferson. The portion of the message of Governor Albion K. Parris, which deals with the Gardiner Lyceum, deserves partial quotation.

> An institution has recently been established in Gardiner, upon a plan original in its design, but promising much solid public utility. The encouragement of those arts, by which the labor of man can be aided and rendered more productive, is worthy of the patronage of any government . . . As the benefit to be derived from this institution will be realized by the agriculturalist and the mechanic it may properly be considered in connection with these employments, as promotive of the public interest, and consequently entitled to the public patronage. (January 2, 1823).

Two years later, the law having constituted the Governor a member of the Board of Visitors of the Lyceum, Governor Parris's message discusses it more at length and concludes:

> There was no institution in which those branches were exclusively taught which are particularly applicable to the agricultural and mechanical employments of the people and to the ordinary business of life. The institution at Gardiner will supply this instruction in such a manner, that the individual who seeks knowledge in one branch only of the useful arts will not necessarily be diverted from his paramount object. . . . Such establishments, which have for their primary object the dissemination of useful knowledge among the productive classes of the community, are obviously entitled to liberal support. (January 7, 1825).

The next governor, Enoch Lincoln, whose older brother Levi, as governor of Massachusetts, was responsible for the establishment of our first state geological survey, was also much interested in education, and commented favorably on the work of the Gardiner Lyceum in his message of January 8, 1829. It was during his administration that the last state appropriation for the institution was made.

THE UNIVERSITY OF VIRGINIA AND THE GARDINER LYCEUM

To associate a state university with a small agricultural school, the very name of which has been forgotten half a century, may seem forced. Yet so striking, in some respects, is the similarity of the Gardiner Lyceum and the University of Virginia that it could not escape the notice of any student of the history of science in this country. They were founded at about the same time, the Gardiner Lyceum opening to students in 1823, the University of Virginia in 1825. Both

depended largely on state aid for support and both, at a time when practically all academies and colleges were directly affiliated with some religious denomination, followed the University of Pennsylvania in remaining free from sectarian influence. The introduction of an elective system in the Gardiner Lyceum has already been referred to, and, as is well known, the University of Virginia was the first collegiate institution in America to adopt this system.

A further resemblance between these institutions is that they introduced, almost a century ago, a system of student self government. The catalogue of the lyceum for 1824 states (p. 9):

> One of the most important subjects, which engage the attention of those, who have the care of a literary institution, is that of discipline. The common methods, from some cause or other, are in a great measure ineffectual, and the fact that they are so under the best instructors, leads us to suppose that something wrong exists in the very principle, upon which they are founded.
>
> These methods have been long in use, were adopted in times very different from the present, and have remained unchanged amid very important revolutions of opinion. They commenced during the prevalence of absolute governments, and are now almost the only vestiges of such governments to be found in countries like our own.
>
> In schools, in which the government is wholly in the hands of the officers, and the students have no part but to obey, they are often subjected to regulations, of which they are not taught the propriety, or which they consider unreasonable, and the result is, they look upon their instructors as tyrants, whose laws it is heroism to disobey.
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> . . . . . .
>
> It is probably to the arbitrary nature of school discipline, which finds no parallel in the political institutions of our country, that we may trace that party spirit in public institutions, which arrays the students in opposition to the government, [and] which oftimes renders obedience unpopular.

The author of the Declaration of Independence himself could hardly have offered a more scathing denunciation of college administrative methods. Indeed, Jefferson's own words in his report to the legislature of Virginia (1 p. 94) seem mild by contrast.

> The best mode of government for youth in large collections is certainly a desideratum not yet attained with us. It may be well questioned whether, *fear,* after a certain age, is a motive to which we should have ordinary recourse.

Jefferson's report and the catalogue of the Gardiner Lyceum further agree in calling attention to the system of student self government then in use in certain English schools.

The most distinctive resemblance between the two institutions is in the fact that both emphasized the practical importance of science, the importance of science in education, and even the relation of science to agriculture. These indeed furnished the very reason for the establishment of the Gardiner Lyceum and they were uppermost in the minds of the founders of the University of Virginia. The attitude of the

"Father of the University of Virginia" on the importance of science in the state (1 p. 89) and of science in education is well known. It is not, however, always remembered that in his original plan (1 p. 83) agriculture was included among the subjects to be taught in the university. Indeed, about the time the Gardiner Lyceum was founded (1822) the Agricultural Society of Albemarle attempted to raise funds for the establishment of a professorship of agriculture in the University of Virginia (8 p. 163). The following quotation taken from the letters sent out at this time by the society and signed by James Madison, then its president and a member of the Board of Visitors of the University of Virginia, undoubtedly represents the attitude of the other university authorities.

> This science [chemistry] is every day penetrating some of the hidden laws of nature and tracing the useful purpose to which they may be made subservient. Agriculture is a field on which it has already begun to shed its rays, and on which it promises to do much toward unveiling the processes of nature to which the principles of agriculture are related. The professional lectures on Chemistry, which are to embrace those principles, could not fail to be auxiliary to a professorship having lessons on agriculture for its essential charge.

A brief quotation from the first "address to the public" prepared by Robert Hallowell Gardiner will show how similar were the ideas of those who founded the two institutions.

> Agriculture, too depends much upon chemistry. It is the business of this science to investigate the nature of soils, the cause of their fertility or barrenness, to ascertain the composition of manure, and the kind best suited to give fruitfulness to each kind of soil. The experience of Lavoisier, who in a few years, doubted his crops, is sufficient to prove the utility of chemistry, when applied to the cultivation of the earth.

In comparing the ideas expressed in the foundation of the University of Virginia and the Gardiner Lyceum, one is tempted to go further and note the similarity of tastes of their founders. They had much in common, a generous hospitality, an appreciation of education and the need of wider opportunities for scientific training, keen interest in farm problems and a love of out of doors. Both even kept careful meteorological records. In political thought, however, they could hardly have been further apart. Indeed, viewed at the distance of a century, Robert Hallowell Gardiner's attitude toward Thomas Jefferson seems like irrational prejudice. The school he established was of the type nearest Jefferson's ideal and had his personal endorsement, the legislature from which the school drew support was overwhelmingly of the party Jefferson founded and was strongly under the influence of his ideas, the very section of the state constitution which authorized appropriations for such purposes was written by the great Virginian and the school at Gardiner was finally wrecked through the pressure of that selfish sectarianism, the power of which Jefferson did so much

to destroy in his own state. Yet throughout his life Gardiner maintained toward Jefferson that attitude of political hostility and personal criticism which was natural in a New England Federalist, who was the son of a loyalist, and a devout churchman. It may be questioned whether Jefferson's partisanship was more generous. It is the more to the credit, then, of these two pioneers in education, that in their interest in education they were ready to forget political differences, that Gardiner sent the prospectus of his school to ex-president Jefferson as well as to ex-president Adams, and that Jefferson, like Adams, sent a "civil answer approving the plan".

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THE RESEARCHER IN SCIENCE[1]

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IT is the custom, at this time, for your president to sing his swan-song and make as graceful an exit from his high office as his natural urbanity—or lack of it—will permit. As retiring president I have chosen the theme of The Researcher in Science for the remarks which I have to make. I may say at the outset that they are intended, not for the veteran researcher, not for the blasé professor who has been bored into dumb, unresisting endurance by an endless succession of such addresses, but they are directed to our newly elected members.

To you, our novitiates, this evening is devoted. Yours is a sacred trust. For it is to keep the heart of science throbbing and to see that this mighty, man-made giant, blind and ruthless of itself, is devoted to the safety and the progress of civilization. In your hands and in the hands of those who come after you it is destined to save or to wreck the world, depending upon the outlook you give it, the motives you instill. The terrible catastrophe of science turned to the destruction of man has been vividly before us during the past few years, and what we have already experienced is but the prelude to what will happen if a later war is to be fought.

You are to be the leaders of to-morrow and you should get a clear-eyed vision of the fact that a heavy responsibility is to be laid upon you. It is no less than the guidance of civilization. Human society has become so complex that no longer can its conduct be entrusted to the man in the street. It must, if it is not to prove the colossal failure of all time, be delegated to the expert. Without intent to flatter, I wish to impress you with the distinction of your position. You are a chosen few from the large number of students of science in our great university. You have been selected because of promise. Your sponsors believe that they have detected in you the divine spark of creative ability which means new discovery, new understanding, new accomplishment in the realm of nature, promise of leadership. And while I want you to feel the honor of this choice, I desire still more that you realize the responsibility it places upon you. It means that in entering Sigma Xi you are pledging yourself to live up to your full capacity. Your motto becomes *noblesse oblige* no less surely than this became the motto of the born nobleman in the days of knighthood. High ability un-

[1] An address before the Wisconsin chapter of The Sigma Xi.

questionably means increased obligation to make the most of that ability.

The emblem of science is the question mark. If you feel no compelling urge in you to know the how and the why of things, then you are not destined to be a scientist; if you have not the desire in your heart, not only to discover truth but to follow it wherever it may lead, and to turn it to the betterment of your fellowman, then you are not worthy of being a scientist.

In world and national affairs if anything is to be read certainly from social and industrial conditions to-day, it is the truth of the Biblical maxim, "Ye are part one of another. * * * For none of us liveth to himself and no man dieth to himself." It is becoming clearer every day that part of the world can not be in distress and the rest carefree. This truth ranges all the way down from the major to the minor affairs of modern life. Particularly in a democracy it is obvious that all must stand or fall together. In the material things of life, for instance, it is being driven home to us daily through the pinch of shrinking purses and annoying inconveniences that we can not exist indefinitely under the pressure of either the profiteering parasite or the greedy laborer; that we can not have an eight hour day in town and a twelve hour day in the country—a fat daily wage in the one place and a lean one in the other. It is equally plain in the sphere of intellect and good taste that we can not have a cultured aristocracy and a boorish proletariat, a group of exclusive intellectuals intent only upon their own cultivation, and a mass of ignorant "hewers of wood and drawers of water." Society as a whole must have a favorable attitude toward the projects and teachings which result from the concentrated endeavor of men of high mentality; otherwise little can be permanently accomplished. This means that not only must the scientist make his discoveries, but he must carry the public with him if he is not soon to reach the limit of public support. As scientists of the future, then, you will not only have to make researches but you must keep the public educated to the value and the necessity of your research.

As a matter of fact, keeping the public posted on the progress of science is, in my estimation, not such a hopeless undertaking as some of our scientific Jeremiahs would make out. I fully believe that no really great scientific discovery has ever been made in the past or is likely to be made in the future which can not be stripped of its technical jargon and reduced to terms that, in its broader bearings at least, render it intelligible to the ordinary, educated citizen. I am one of those incurable optimists, moreover, who believes that to interest the layman, every new discovery in science need not have some obvious practical use attached to it. Nor do I believe that appeals for popular support need to be based on the economic aspects of science only. For once, at least, I

should like to see some one with the knack of clear presentation and a conviction of the justice of his cause, go before the public with the direct plea of science for its own sake. I believe that the appeal would meet with a cordial response. It is so easy to show that all truth must in the long run redound to the advantage of man in other than material ways, that we lose much of our effectiveness when we confine our arguments for support to those aspects of science which mean merely a fuller purse or a fatter paunch, a more profitable mine or a more effective machine.

We hear not a little in these days about science and the humanities—that is, we hear not a little about them from the professional humanists. The word "science" in this setting is sometimes spoken with a sort of haunting fear as though the downfall of beauty, sentiment, and poesy were at hand. Science and these elusive entities vaguely termed the humanities seem to be regarded as in some way antipodal and antagonistic. To be sure we are told by Trench that the Romans meant by "humanitas" the highest and most harmonious cultivation of *all* the faculties and powers, but their modern successors seem to have changed the inclusive *all* to the restrictive *some*, that is, they apparently exclude the faculties and powers which have to do with science.

When a scientist, seeking enlightenment, makes a determined effort to lay hold upon the idea labeled "humanities," in the broad modern usage of the term, he comes back at last with such morsels as these: cultivation of the emotions and perceptions; interpretation of the soul of man; interpretation of past human experience, emotional, rational, etc.; elevation and refinement of taste; knowledge of human nature as revealed in literature and history; development of ideals; interpreting ideals of beauty; culture.

He may be a bit puzzled by the indefiniteness of his catch, but still all of the conceptions have a familiar look and feel, and he begins to wonder just why they are regarded as the exclusive prerogatives of the non-scientific. He has encountered them all in literature and even more vividly in his attempts to further the cause of humanity by solving the problems of nature. Just because he has an ineradicable conviction that the universe is intelligible if he can only discover enough links of the chain of cause and effect, and is bending his chief efforts toward working out this faith that is in him, he fails to see just where he falls short in his desire to cultivate his emotions, develop ideals, refine his taste, and interpret the soul of man. He has thought all along that these were some of the important things he was doing. In fact he would, I suspect, define the main objects of education about as follows: to learn how to extract knowledge not only from the past, but also from the things around us, and how to use such knowledge; to learn to weigh evidence that we may know how to deal with facts and to evaluate the conclusions of others; to gain understanding of the fundamental laws

of nature that we may work in harmony with, rather than fall a prey to them; to learn to express our thoughts clearly, forcibly, and with a reasonable degree of grace; and to form character and develop an intelligent appreciation of the things which enrich and refine life. To be sure, he does not work much through intuition or pure fancy, or subservience to authority, and he looks somewhat askance upon products of such an origin. He believes furthermore, that the world of the emotions which, I suspect, we unconsciously imply when we talk of the humanities as consoling us in adversity or revealing human life and feelings, is likely to prove an untrustworthy guide unless grounded upon the hard substratum of objective facts. He makes use, for the most part, of what he terms the method of science.

With its mode of procedure in mind, Huxley once defined science as "trained and organized common sense." The method of science is not, then, some abstruse system which is being expounded, nor a recently discovered panacea for mental aberrations. On the contrary, it is as old as the time when a mind first existed capable of distinguishing the relations of things. So common is it that, whether merchant, mechanic, child or scientist, we use it in a simplified way in nearly all our daily occupations. The method has been expressed in words in one form or another by many logicians and educators, that we might, by focussing our attention upon it, recognize its value more clearly and use it for the more economical guidance of our minds. The principle when thus formulated becomes a sort of handrail to our mental stairway which keeps us from tumbling down into the realm of inanity, illusion and superstition. It is one of those great modes of mental activity which, more or less unconsciously, all follow, but which, like steam in a cylinder, become power to a purpose when followed consciously.

When he invades the realm of the humanists, the prying scientist soon discovers that these self-appointed arbiters of culture and humaneness are not in agreement among themselves as to what is the Simon pure brand of their ware. Seemingly, one has almost as much choice in alternatives as he has of styles in theosophy. He finds such major labels as classicism and romanticism together with a whole host of subordinate ones. Clearly, the humanists still have some time to bicker among themselves, apart from that spent in decrying the gross materialism of science and weeping over the vanishing auras of culture. I say auras because, as stated, you can never get them to agree on just what the particular aura is that is being lost.

After one becomes a bit acclimated to this rarified atmosphere one makes the interesting discovery that the real creators in this realm, the poets, philosophers and makers of *belle-lettres*, are not the complainants. Scarcely any one more than the poet, in fact, has made avid use of the findings and doings of science. One needs but to pick up his Tennyson, his Browning or his Kipling to verify this to the full.

But let us admit at once that some scientists are crass, plodding specialists who have neither breadth of vision nor depth of soul. And let us also express the suspicion that some humanists belong in an equally narrow, uncompromising class. Just as there are beetles whose sole place in the scheme of nature seems to be to hunt up dead mice and other small lifeless creatures and either devour or bury them, so there are individuals, apparently, whose idea of culture is the devotions of one's life to devouring the fragments of various dead languages, not with the idea of revealing to their less accomplished brethren whatever there may be of valuable thought or sentiment concealed there, but for the mere joy of the feast. Now no one will deny the useful part the sexton beetle plays in the world, nor does any one doubt the great service the classicist can really do for us when he stops tinkering with the mechanism of language long enough to reveal to us some of the great thoughts conveyed by it. Neither would any scientist quarrel with even the classicist given over entirely to necrophilism if the latter did not keep on insisting that his is the only real portal to culture and beauty.

Am I tilting against a man of straw? Let me cite a specific example. Some time ago I was walking along a ravine through a beautiful park with such an aesthete of classicism. The prevailing trees of the vicinity were giant beeches, and with their fresh new leaves, gray trunks and drooping branches they were a joy to the eye. The ravine itself was bordered with a profusion of the lesser trees and shrubs of the woodland. A shower had just passed and the drops of water still clinging to the leaves flashed back the gold of the late afternoon sunshine. Many of the choicer early spring flowers still lingered in the depths of the ravine—the bloodroot, the wild ginger and the trilium. The evening song of the woodthrush was all around us and a specimen of the rare hermit thrush shyly glided through the underbrush. A trim fox-sparrow eyed us pertly from beneath a nearby shrub. One good deep breath of the newly washed air was like a fresh draught of life. Upon remarking on the beauty of the scene I was met with the rather bored rejoinder, "Yes, but for it to be really beautiful there ought to be pieces of statuary here and there among the trees, and the ruins of a Grecian temple visible in the distance." Then with eyes bent to the bridle-path along which we were strolling he babbled on of beauty.

Verily, if this be a fair sample of what classicism yields, then in preference to it I suspect most scientists would cry, "Back to intellectual Nirvana and an instinctive life with the creatures of the wilderness!" Certainly the picture of the beast-world as Walt Whitman paints it is far more alluring:

> They do not sweat and whine about their condition,
> They do not lie awake in the dark and weep for their sins,
> They do not make me sick discussing their duty to God,
> Not one is dissatisfied, not one is demented

With the mania of owning things;
Not one kneels to another, nor to his kind that lived thousands of years ago;
Not one is respectable or unhappy over the whole earth.

Fortunately, however, my example is not a fair one, but it is no more unfair than those you see exhibited not infrequently to typify the scientist. Such a classicist demands attention only because of the assiduity with which he fights the intrusion into our educational programs of anything bearing the mark of science, although he himself is often innocent of any knowledge of the subject. It should be well understood that there is no quarrel with classicism itself. Many scientists have a high regard for both Greek and Latin and wish most heartily that their students had had some training in one or both. Aside from the question of other values, the single one of inculcating something of the significance of words is certainly one that appeals to most teachers of biology, for now-a-days the simplest technical term, etymologically considered, is to most of our protégés, as one of my students put it, "only a funny noise." For purely selfish reasons, if for no other, I for one, should like to have students come to me with some knowledge of Greek and Latin roots, and practice in making derivations.

There is another type of less classical demeanor which merits passing attention. Fortunately again this type is relatively rare, though it makes up in obnoxiousness what it lacks in numbers. It professes humanism rampantly, though I suspect that real humanists would disclaim it. It deserves only such diagnosis as will enable us to avoid confusing it with men of real culture and discernment. Like the wise men of Biblical tradition, not infrequently it comes to us out of the East, shedding sweetness and light at every stride. It invariably pronounces *b e e n, bean*—lovingly and lingeringly, as though culture sat enshrined in this single word. It is fond of discoursing on the ideals of culture at, let us say, W— University compared with ideals at X— University, from which it sprang; always, of course, to the disparagment of the former. If music, art, literature or philosophy is the theme of conversation, it is always ready with an authoritative dictum—its own—of what's what or who's who in these realms. In its defense, the plea may be made that usually it is young, and presumably it dies early, for it is rarely encountered after its fortieth year. If you meet it, don't be perturbed by its strictures on science; science will survive.

As he listens day by day to the diagnosis of the situation at the hands of his humanistic friends, the scientist hears more frequently perhaps than any other, the word *culture*, and gradually the conviction arises that humanists regard culture and humanism as practically synonymous terms. He suspects, moreover, that some of them feel,

deep down in their hearts, that they have some sort of monopoly on appreciation of the thoughts, deeds and motives of the cultured world of to-day and yesterday. The implication seems to be that in turning to science the misguided one is somehow missing the refinements of life. If you are to believe them, apparently, the scientist can not, in imagination, "wander lonely as a cloud that floats on high o'er hill and dale" because to this literal mind a cloud is only vaporized water, and inanimate things can not be lonely. Nor can his heart dance with the daffodils because strictly speaking *Narcissus pseudo-narcissus* does not dance.

> When the wind is low and the sea is soft
> And the far heat-lightning plays
> On the rim of the west where the dark clouds rest
> On a darker bank of haze

should remain a meaningless jumble to him because his mind must inevitably be distracted by the fact that, strictly speaking, the west does not possess a rim. It can not be sweet for him

> ——to hear the faithful watch-dog's honest bark
> Bay deep-mouthed welcome as we draw near home

because, presumably, he regards the dog as only so much laboratory material. If by some mischance he wanders into Southern Italy, he can not be struck with the symbolism of the asphodel, "pale flower of Hades and the dead," which riots over the crumbled walls and around the deserted temples of Paestum, because he must be preoccupied with the knowledge that the asphodel is a plant with fleshy fasicular roots, tufted radical linear leaves, long racemes of lily-like flowers on scapes, and that it is a perennial herb of the family Liliaceae. Besides, there is a suspicion that Paestum, far from having a romantic history, was an ordinary swampy settlement from which the inhabitants were driven by the onslaughts of malaria. Again, his mind must be closed to impressions pictured in the mystical blue lights of unusual fancy—as by Hawthorne in literature or Grieg in music—since fancy is not reckoned as a tool of his trade.

However, the scientist is very likely to meet these implications with the challenge, "What is your evidence, and by what authority have *you* become mentor?" Or in the query of the Israelites to Moses, "Who made thee a prince and a judge over us?" Have you had equal training in the sciences and the humanities, or are you presuming to pass judgment in the matter without really ever getting into the spirit of modern science? In listening during the last twenty-five or more years to the perennially recurrent debate over the relative educational importance of science and the humanities, or more narrowly sciences and languages, I have always been struck by the fact, apart from the intrinsic merits or demerits of the case, that many of the scientists had

a reading knowledge of French or German or both, and could boast at least a passing acquaintance with Greek or Latin, while their opponents rarely knew any science through direct contact in laboratory or field. In fact, in not a few instances the crowning glory of the latter, in their own estimation at least, appeared to be that they had kept themselves unsullied from that world of unrighteousness. Some of them seemed not to have even an inkling of the fact that to understand science is not merely to be aware of or experienced in its material achievements; that it is not only ability to use its tools and on occasion express one's self in the abbreviations which constitute scientific terminology; but that it is also to see in it the struggle of the human mind toward new concepts of nature, and to realize the place of such concepts in the fabric of civilization.

Science has, indeed, a much broader significance than application to immediate ends only. To level one's whole effort to meet the shifting needs of present occupations is, so far as true progress is concerned, clearly suicidal. Science should never be regarded as a mere commodity or means of subsistence. Human progress requires application of our knowledge, to be sure, but we must never lose sight of the great fact that discovery and explanation must precede application. Value of mind must always come above value of money and the first question of the scientist should be, not "Is it useful?" but "Is it true?" If true, then *pari passu* it is useful.

The conventional distinction between pure and applied science is in fact partly academic. A vast proportion of the material advantages of modern civilization rests on results obtained by the scientist unmotived by the immediately practical. Perhaps no conquest of nature is more impressive than that of wireless telegraphy, yet this utilitarian accomplishment was made possible only through the discoveries of Professor Hertz, a pure scientist, in his studies on light and electricity. On the other hand, perhaps nothing has done more to stimulate new researches than has practical wireless telegraphy. Almost any schoolboy can to-day cite striking instances of economic applications of principles or facts discovered without any thought of their utility, and any technologist will tell us that he can not scrape through even the veneer of his practical problem before he heads full tilt into countless other problems which require all varieties of science, pure, impure and mixed in their solution. Thus even the most thoughtless can easily see that to interfere with pure science is to kill the goose that lays the golden egg.

However, I would not belittle the part that our daily bread plays in fostering even the humanities. According to Westermann, the prosperity, and with it the culture of Ptolemaic and Roman Egypt, waxed with increase of wheat production and waned with its decline. Upon the passing of the extensive system of irrigation which had wrested fertile

lands from the desert and maintained them at a high degree of productivity for hundreds of years, the desert claimed its own again, and the brilliant intellectualism of that ancient world vanished.

Not long ago, I heard a historian express his disapproval of a contemporary with the statement that B— was not a historian but a scientist, thus revealing his own conception of a scientist as a mere collector of facts. Instantly there flashed up in my mind the memory of a revered teacher of my young manhood, who, though untiring in his quest for necessary facts and meticulous in his demands for accuracy, held before us the constant reminder that, in his own words, "fact knowledge is the fool's paradise," and that "an ounce of ability to turn facts into general ideas is worth tons of information," and I reflected that my friend the historian still had much to learn about the true spirit and significance of science. It so happened that within less than twenty-four hours a scientific colleague expressed the idea that C— was not a scientist but a mere historian; that is, presumably, a chronicler of events. And I had opportunity to reflect again; this time to the effect that the scientists no less than the historian may be afflicted with seriously myopic vision when he views the other man's domain.

And is not this emblematical of the whole difficulty? Each knows too little of the other's point of view; each misunderstands the other's motives and accomplishments. This is a malady of world-wide range which is not restricted to the supposed conflict between science and the humanities. As we have already seen, it is common within the humanities themselves, and it certainly is prevalent within the sciences. Even in so restricted a realm as that of music we discover no end of disagreements and miscomprehensions. In looking through a reminiscence of Tshaikovsky some time ago, for instance, I was impressed by the fact that although this master of tone-drama—creator of the somber *Manfred* and of the melancholy *Symphony Pathétique*—admired Wagner personally, he expressed his utter inability to grasp what this great artist was trying to do in his music drama. And toward Brahms, who, because of his adherence to established forms, had unwittingly become the champion of the anti-Wagnerian party, Tshaikovsky reveals an actual antipathy, saying that Brahms coquets with the intricacies of musical composition to hide his poverty of ideas. Yet Brahms is almost universally admired by other technical musicians and is regarded as one of the greatest creators of music which is original, beautiful, and of faultless form. With such disharmony of opinion in what is supposed to be the most harmonious of the arts, is it any wonder that the place of science in the realm of human culture may be variously appraised by different cultured people?

Even when we speak or read the same words we may understand by them very different things, since we are almost sure to impute to them meanings derived from our own mental content. How easily this mis-

take can be made was brought vividly to my attention only a few days ago. In an idle moment I had picked up the volume of Thomas à Kempis "Of the Imitation of Christ," and was sampling it here and there. In Chapter 3 of the first book, I chanced upon the expression "And what have we to do with genera and species? He to whom the Eternal Word speaketh is delivered from many an opinion," and came up with a start. To the modern evolutionist, that could only be an echo of the Darwinian controversy, and yet as a matter of fact the volume in question was written in the early part of the fifteenth century, three hundred years before Linnaeus led us toward the modern usage of the words genus and species, and over four centuries before Darwin was born.

It is to a certain extent a matter of opinion, of course, as to what constitutes culture; but in the main, many educated people of to-day will agree that the best culture is that subtle attribute which comes with proper education, simultaneously quickening the intellectual, the moral, and the esthetic sides of man's nature. It is not learning alone, but learning refined into wisdom and intelligent social activity. Matthew Arnold's familiar definition of it as "the study and pursuit of perfection" is known to you all. But he did not limit it to pursuit, for he said we are justified in the quest for perfection only "to make it prevail." His idea of culture was, then, not only acquisition of knowledge, but also its utilization for the betterment of man.

Are we essentially more cultured, if in fancy we watch some goat-legged god go capering through the pastures and forests or along the streams of Arcadia piping to the wood nymphs, than if we actually go into the woods and along the streams in search of our friends in feathers or fur, watching their home-making, learning their habits, understanding the part they play in nature, enjoying their beauty of form, action or song? Are we necessarily more learnedly, ethically or esthetically employed when we are gazing down through the portals of a borrowed mind—say Dante's—into the murk of hell, or ascending with him through the seven planetary heavens to the empyrean, than we are when striving to analyse the obscure motives of man in terms of the behavior of lower animals where many of them stand unveiled, or in studying the part living things play in the world, and man's relation to them, so that his place in nature shall not always remain a sealed book to him? Each type of occupation unquestionably has its own value. Dante, so aptly termed the "voice of ten silent centuries," depicts allegorically the wrestling of man's soul with the problems of human existence; science represents the wrestling of man's reason with the world as it is, to the end that human existence may become based less on fantasy, more on fact.

If proper balance of tone, contrast and color are to be secured in a great orchestra, not one family of instruments—strings, wood-winds,

brass or percussion—can be dispensed with. Think what a hiatus would result between strings and brass if the wood-winds were lacking; or if even the horns, which in orchestral usage merge the wood-winds with the harsher brass, were missing. What could take the place of the trio for horns in the "Eroica," or the horn solo in the scherzo of the "Pastoral" Symphony, or the well-known passage for four horns in "Der Freischutz"? The peculiar tonal quality of each separate instrument, indeed, whether considered individually or in combination with other instruments, is essential to the finished effect. The expressiveness of the bassoon, bass of the wood-winds, is inimitable in certain sustained melodies like that given to it in the Weber Mass in G, "Agnus Dei"; so, too, is its drollery in the hands of good old Father Haydn, or its ghastliness in Meyerbeer's resurrection of the nuns, or Handel's scene between Saul and the Witch of Endor. What else could impart the spirit of gayety, or, on occasion, of melancholy, that that autocrat of the orchestra, the oboe, does? Or what can pander more to savagery in musical taste than the yelping, braying saxophone, hybrid of reed and brass, which so intoxicates our modern devotees of "jazz"? The point I would make is, that just as a great diversity of instruments of distinctive individual and group qualities must be combined to secure the marvelous effects of the symphony orchestra, so the blending of a wide range of sciences and humanities is indispensable to well-balanced modern culture.

Thus no one aspect of learning is sufficient. The study of science in some form should be accorded a prominent place, however, because of its obvious bearing upon the principles involved. It is the most direct of all learning, and from the very necessity of obtaining correct knowledge through personal contact with the facts concerned, it engenders in large degree the ability "to make it prevail." Training in science, therefore, must demand recognition as one of the fundamental components leading to that perfection which, with Arnold, we may recognize as the goal of culture. "Perfection * * * is a harmonious expansion of *all* the powers which make the beauty and worth of human nature, and is not consistent with the over-development of any one power at the expense of the rest."

Even if we choose such aspects of culture as art, we can not escape the fundamental necessity of accurate observation and clear reasoning—the very essence of science—and this is as necessary to literary art as to other forms. For before we can have art in literature, we must first see the truth, then state it accurately and clearly. Walter Pater, one time apostle of precision and fitness in style, says, "Truth! there can be no merit, no craft at all, without that. And further, all beauty is in the long run only fineness of truth." That accuracy in the use of language which must result if one records his observations faithfully, then, must be one of the foundation stones upon which literature as art is builded;

for if we are to believe this critic, fine art in literature results only from the writer's effort to transcribe the essence of the truths which he perceives; not necessarily, to be sure, the actual specific fact, but "his sense of it," and the result is "good art in proportion to the truth of his presentment of that sense."

We sometimes hear the curious assertion that training in science tends to destroy the powers of imagination, that it renders one prosaic. But what has suggested any of our great laws or principles in the world of science, if it has not been a legitimate working of the imagination? It was the imagination of Sir Isaac Newton that led him from the simple perception of a falling body to the great law of gravitation, whereby we have compassed the heavens and are able to follow the celestial bodies with the precision of clockwork. It can be nothing else than the imagination which has disclosed the realm of the imperceptible molecule and atom, or in the discovery of electricity enabled us to outdo Puck in putting "a girdle round about the earth in forty minutes." Or what but the imagination, based on scientific fact, has carried us back step by step peering into the depths of ancestry till we perceive the remotest dead, and has thus enabled us to formulate the great law of organic evolution? In truth, as pointed out long ago by Tyndall in a famous lecture on "The Scientific Use of the Imagination," to science should be attributed a legitimate cultivation of the imaginative faculty rather than its destruction. To flights of pure fancy unhampered by knowledge or common sense, however, science is perhaps less cordial.

And last of all let us take cognizance of beauty, that quality which appeals to, and gratifies, our esthetic sense. Where else than in nature can one find more of that perfection of form or circumstance, of harmonious combination, which is the essence of beauty? Only one trained in interpreting the processes of nature can, in fact, see its greatest beauties. To such a one a graceful tree has a tenfold beauty unsuspected by the casual observer. It is not only a thing of symmetry and of life, a harmony of color, or a picturesque bit of the landscape; it is infinitely more. Its every attitude, every part, is a response to the wonderful energy of the universe. Locked in every leaf is the secret of creation which can wrest life from the sunbeam and embody it to our view. The very arrangement of bough on trunk and leaf on bough points to the silent struggle of each to gain the most favorable position for this transmutation of life. Its roots, prompted by an inner impulse of response to the external world, no less marvelous than that of leaf and bough, thread their way in darkness for the soil-food and water which shall later with the ingestions of the leaves form the mechanism of living substance.

From the standpoint of beauty our wild animals are not only graceful creatures suited to ornament some menagerie or zoological park;

they are not merely a delight to the eye because of form, color or action; but they are also living examples of that higher beauty to be perceived through a comprehension of the marvelous fitness of living things to their environment. One trained to read such records need not stupidly go to a natural history every time he wants to find out the essential facts about some particular animal, for the account of its native haunts, its habits of life, the nature of its friends and foes are before him in the living animal itself. The spotted coat of the forest, the stripes of the jungle or the meadow, the dunes of the desert, the whites of the polar regions, the symmetry and proportions of body, the claws or hoofs, the beaks or teeth, the position of the eyes, the characteristics of the ears, nose or jaws, in short any particular part of the body when taken with the equally obvious context to be read elsewhere in the animal, tells its unmistakable story.

To one who can interpret, the flower, in addition to mere formal beauty and fragrance, has a wonderful history to disclose of ingenious device, which reaches even to the other world of life, the world of sentient beings, and forces bee or butterfly to serve its ends. The trained observer may see, furthermore, in every spear of grass or every forest tree an emblem of triumph; for has not each through endless struggle won victory? It is the understanding of this victory which enables the seeker after truth to pry even into the very inception of all life and form, whether plant or animal, and point the path by which it has arrived at its present perfection.

And not only in the field of animate nature, but in the realm of astronomy with its romance of worlds in the making and worlds in decline, with its myriads of solar systems in incredible gyrations, yet all apparently orderly and harmonious; in chemistry with its wonderful systems of combination and exchange, of creative possibilities that beggar the lamp of Aladdin; in physics, forging ahead with astonishing strides into the solution of matter itself and of all performances of matter; in geology with its ingenious readings of the past in earth shrinkage, crust warping and climatic oscillations, with its re-creation for us of successive ages of flood and ice, land and sea, of strange monsters long since vanished; in all of these there are worlds upon worlds of beauty unsuspected by those who are strangers to the paths of science.

Thus from the standpoint of esthetics, nature becomes to the student a wonderful harmony. As he perceives something of the mechanism of the universe, how each part moves cog within cog in marvelous unity, knowledge does not reduce his emotional enjoyment, but enhances it through a higher sense of beauty.

When all is said and done, after admitting that many scientists have their crudities and some humanists their asininities, we must realize that science and the humanities have far more in common than they have apart. The old idea of conflict between them is largely fictitious.

They are or should be cooperants, not antagonists. For the most part they look toward the same problem, in last analysis the great problem of what is worth while for humanity. They but view it from different angles. And it will be a sorry day, not only for science but for civilization itself, if scientists ever lose sight of the humaner aspects of their problems. It is my serious conviction, indeed, that one of the imperative, outstanding duties of the modern scientist is to do away with what remains of the no-man's-land between these two great aspects of human culture and blend them into one. No one more than the thoughtful scientist recognizes to-day that science in the sense of mere material accomplishment, of greater accumulation of knowledge, or of more precise logic—if this be all—is futile; it must be humanized. Without the final touch of human altruism, science may easily become a soulless Moloch which will devour its own creators.

Further applications of scientific knowledge unquestionably will mean growing complexity of social organization. And our organization is already so intricate that a slip anywhere in the machinery, be it but the obstinacy of a few striking switchmen or the discontent of a handful of coal miners, may throw the whole machine into disorder. With the dependence of one upon another to which we are becoming more and more committed, serious disruptions of the system become increasingly probable and increasingly hazardous.

In his more pessimistic moods, when he ponders the trend of present economic and social conditions, the mind of the evolutionist harks back to the grotesque monsters of Mesozoic times whose very hugeness probably led to their final extinction, and he is filled with apprehension for the outcome of the human race. This much is sure, human society will need all of brotherly love, all of tolerance, all of the refinements of existence that scientists and humanists can muster jointly, if the giant organism known as civilization is not to succumb to its own intricacy.

It becomes your duty then as a part of the rising generation of scientists to do your share toward imbuing science with a soul, and one of the easiest ways of doing this is to help promote the humanities as you do your science, in every way you can. The relation of man to his fellowman is no less important than the relation of man to his physical environment. Recognizing as we companions of Sigma Xi do that research is the highest form of human activity, let us not take a narrow view of it. The goal of science and of the humanities alike is truth.

The desire for truth, indeed, is a well nigh universal human attribute. The many observances and beliefs common to all the great religions symbolize the cravings of the human mind for truth. Thus the Vedanta maintains that the final deliverance of the soul from its burden of repeated carnal existence can be attained only by the removal of ignorance. In the teachings of Zoroaster we find that chief among the "worshipful ones" who guide the forces of nature is Mithras, per-

sonification of light and truth. And as for the Buddha, his very name comes from a word which means "he to whom truth is known." More familiar still is the pronouncement of the gentle Nazarene, "Ye shall know the truth, and the truth shall make you free."

The great poet, the true artist, the sincere novelist is striving in *his* way for truth, for reality, in no less a measure than is the physicist or the chemist. And the most cursory glance into the past shows that this has been so thoroughout all history. We find Aeschylus, five centuries B. C., grappling in his poetry with a conception of the mental evolution of man. His graphic description, in his *Prometheus Bound*, of the part number and the rudiments of science played in the awakening of man from blind instinct into reason is well worth considering (translation of Elizabeth Barrett Browning):

> How, first beholding, they beheld in vain,
> And hearing, heard not, but, like shapes in dreams,
> Mixed all things wildly down the tedious time,
> Nor knew to build a house against the sun
> With wicketed sides, nor any woodwork knew,
> But lived, like silly ants, beneath the ground
> In hollow caves unsunned. There came to them
> No steadfast sign of winter, nor of spring
> Flower-perfumed, nor of summer full of fruit,
> But blindly and lawlessly they did all things,
> Until I taught them how the stars do rise
> And set in mystery, and devised for them
> Number, the inducer of philosophies,
> The synthesis of Letters, and, beside,
> The artificer of all things, Memory
> That sweet Muse-mother.

Somewhat later we note the endeavors of Plato to make knowledge and conduct go hand in hand, and in his pupil, Aristotle, we see perhaps one of the most ideal combinations of scientist and humanist in one that history reveals. Still farther down the ages we find Lucretius not only propounding a theory of the confluence of atoms into stable and adapted forms, but even foreshadowing the idea of a struggle for existence, the conception which became of such importance in the Darwinian theory. Thus, " * * * And many races of living things must then have died out and been unable to beget and continue their breed. For in the case of all things which you see breathing the breath of life, either craft or courage or else speed has from the beginning of its existence protected and preserved each particular race. * * * In the first place, the fierce breed of lions and the savage races their courage has protected, foxes their craft, and stags their proneness to flight."

With all of these, as with the scientist to-day, the unmistakable note is the quest for truth. So that we scientists in our pre-occupation with

our own fragments of truth must not overlook the fact that the expressions of human emotions, character, taste, and cultivated imagination, all have their share in the finished product of our search. In fact, when we stop to consider, it is obvious that the motives for our conduct, our likes and dislikes, lie far more in the realm of the emotions than in that of the intellect. And all history implies that man can no more live without beauty than he can live without bread.

> Beauty is truth, truth beauty—that is all
> Ye know on earth, and all you need to know.

Even the prehistoric cave-man showed his craving for beauty in crude attempts at picture-making. The colored drawings may still be found on the walls of his caves. The warring, pirating Greeks bore a Winged Victory at the prow of their boat. In the Middle Ages, while the shepherds of the church were burning heretics, great artists were painting Madonnas, great architects were erecting magnificent cathedrals to the glory of God, great writers were giving voice to the tortured, struggling, inarticulate soul of humanity. Seek any period in history, no matter how sordid, how tyrannical, how merciless man in the aggregate may have become; there was always abroad somewhere in the land the spirit of beauty, the leaven of humaneness which in the end redeemed the whole.

> And where is he shall figure
> The debt, when all is said,
> Of one who makes you dream again
> When all the dreams were dead.

And we may note to good advantage also that our knowledge of such facts as these has come down to us mainly through the efforts of humanists. Without them what indeed should we know of "the beauty that was Greece and the grandeur that was Rome?" The nations themselves have long since passed into the night, but their thoughts, their motives, their accomplishments have been added to our own civilization, thanks to the tireless efforts of our classical scholars. And who shall say how much of the efforts of these scholars was science, how much humanism?

As a matter of fact, the reconciliation of science and the humanities, in spite of complainants sometimes heard to the contrary, is already in progress. This is evinced, on the one hand, in the increasing drafts the humanists are making on the methods and materials of science, and through their tacit or avowed acceptance of the worth of science and, on the other, by the spirit of greater tolerance exhibited by scientists. Even in the short period between the present and the close of the nineteenth century, one can notice a decided change of attitude on the part of science. The cocksureness and belligerency of the earlier period has softened into a willingness to reconsider evidence and a spirit of friendliness towards all types of scholarly endeavor. To-day, while his at-

tempt to explain things mechanistically does not falter, the scientist recognizes more clearly the limits of possibilities.

The reason for his earlier attitude, however, is not far to seek. In the last century, particularly following the proclamation anew of the theory of organic evolution by Darwin and his followers, science in general, though especially biological science, suffered the fierce onslaught of the powerful leaders of the day, the clergy, who saw their authority challenged, their privileges threatened. Driven to fight this hostile element for the very life of science, the result was just what might have been expected—the exaggerated dogmatism of a Haeckel or the caustic tongue of a Huxley. The latter, with his crystal-clear style of presenting the facts of science, his bulldog pugnacity and his quick wit, was particularly effective. Now we find him urging one of his hecklers who could or would not understand what he was saying, to use the full length of his ears and he would surely understand. On another occasion, in his famous tilt with Bishop Wilberforce, he expresses his preference for a respectable monkey as an ancestor to relationship with a bigoted bishop who uses his great gift to obscure the truth. Again we hear him pronouncing the conviction that "Extinguished theologians lie about the cradle of every science as the strangled snakes beside that of the infant Hecrules." Such retorts as these show what the provocation must have been, and it requires little further exercise of one's powers of inference to discover why the science of the nineteenth century had the ring of dogmatism. Unquestionably the modern researcher has Huxley to thank for much of his own immunity from such attacks.

But to-day the clergy have come to see that a God of an orderly universe is quite as acceptable as a God of an arbitrary chaos. The educated clergyman now recognizes the importance and more or less of the significance of science, even of evolution, and is finding more than enough to keep him busy in the immediate problems of the human soul without worrying so much about its future. He is content to give us help in the present instead of hell in the hereafter. His aid in keeping the spirit of altruism alive in the world, in upholding ideals, in winning men from the fiercer passions of life, was never more needed and never more tolerantly and wisely given than it is to-day.

But as scientists we are not so much interested in the duties of some other profession as we are in our own. The only excuse I would offer for stepping outside bounds is that if we are to have perspective in our work, if we are to secure a clear vision of future world problems we must see these problems from various points of view and realize that our duty is not done, our fullest possibilities are not realized, until we have fitted our findings as researchers into this general scheme of things. To have but a narrow angle of vision is to miss most of the

richness of life and much of the good we can do for our fellowman. We want to escape the type of accuracy exhibited by the literal-minded printer who, upon coming to the quotation, "Sermons in stones and books in running brooks," corrected it to read "Sermons in books and stones in running brooks."

To each of you as researchers civilization is entrusting its future. It is yours to do great deeds, to dream great dreams. And you may well remember that "the dreamer lives forever while the toiler dies in a day." To most of you will come the seemingly small, but actually the fundamentally important duty of making accurate records of observations and conclusions, together with necessary qualifications and limitations. This is indispensable as a foundation for one's own scientific procedure and is equally important as the basis of fact from which others may take up the duties of discovery after the recorder has passed away. To some of you may be given that rare vision which will enable you to weave together from the ever accumulating strands of scientific truth some new far-reaching generalization. But whatever your part, be it great or small, be assured of its dignity, of its worth, as long as it is honestly performed. You may not live to see the great poet honored more than the successful politician, nor the great scientist more valued than the wealthy trader, but you can at least throw the weight of your influence into the proper scalepan. Yours is a rare opportunity to create, to produce, and I know of no better admonition to urge upon you than this sentiment expressed in the clarion call of Carlyle:

> "Be no longer a Chaos, but a World, or even Worldkin. Produce! Produce! Were it but the pitifullest infinitesimal fraction of a Product, produce it, in God's name!"

In closing, may I urge again that for the researcher, ideals as well as achievements are indispensable to progress, and that both must often run far in advance of what for the moment may seem practical. If the world is to be ruled by truth rather than by tradition and the chance compensation of errors, you and others like you who are entering into the scientific communion of Sigma Xi must give up your life to continuous processes of thought and experimentation. Since the creative mood demands quiet, poise and concentration, you will have to make a constant fight to see that your strength and ability are not drained off by trivial and irrelevant demands into non-productive channels. You will doubtless be called upon to make financial sacrifices. And your reward? Your reward will be consciousness that you have fulfilled your real function of discovering truth, diffusing knowledge and developing ideals.

> Have I named one single river? Have I claimed one single acre?
> Have I kept one single nugget—(barring samples)? No, not I,
> Because my price was paid me ten times over by my Maker.
> But you wouldn't understand it. You go up and occupy.

And while I am quoting Kipling, I shall leave this other bit with you as voicing the real spirit of the researcher:

> Till a voice, as bad as Conscience, rang interminable changes
> On one everlasting Whisper day and night repeated—so:
> "Something hidden. Go and find it. Go and look behind the Ranges—
> Something lost behind the Ranges. Lost and waiting for you. Go!

FEARSOME MONSTERS OF EARLY DAYS

By Dr. LEON AUGUSTUS HAUSMAN
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THE reading of natural history has ever been a popular pastime among young and old. As living beings we are supremely interested in the phenomenon of life; first as it is manifested in creatures of our own kind, and second as we see its animating power vitalizing the many animal forms about us. We take keen delight, moreover, in hearing accounts of the curious and the strange; in listening to tales of hunters of big game as they tell us of extraordinary creatures in lands beyond the sea, or in reading the narratives of whalers who describe the habits of the monsters of the deep. We know much, in general, concerning the animal life of the world today, at least concerning those creatures large enough, or common enough to have made their presence known to man. Through the medium of photography, through the collections of living forms in our zoological gardens, and through foreign travel, we have become familiar with the appearance of many creatures, with which we would not otherwise have been acquainted.

The peoples of earlier days, however, were less fortunately situated with respect to ease of acquiring natural knowledge. Their sources of information in this field were a meagre collection of works, compiled in the main from the ancient writers, and the tales of a limited number of credulous travelers.

Few persons, perhaps, know with what sort of creatures the world of the early naturalists was populated. Doubtless many of us remember the tales of the griffin, unicorn, dragon, and others, which were told to us out of the old rhymes and fairy stories of our childhood. These were glorious creatures, never failing to appeal to the imaginative instincts which make childhood so attractive a period to us as we look back upon it from the world of unpoetic realities! The dragon and unicorn and their ilk, have survived the times and have passed into the literature of the race. But they represent only a fraction of the vast host of marvelous creatures, whose names and attributes are now known only to scholars; creatures in whom the early writers and their readers placed full confidence; creatures which were soberly discussed and pictured in the early volumes of natural history.

Books on natural history were extremely popular in the fourteenth, fifteenth, and sixteenth centuries; and as soon as the art of printing (introduced about 1450) had made available to a large number of

THE
HISTORIE
OF
SERPENTS.
OR,
The second Booke of liuing Creatures:

Wherein is contained their Diuine, Naturall, and Morall descriptions, with
their liuely Figures, Names, Conditions, Kindes and Natures of all venemous Beasts:
with their seuerall Peyles and Antidotes: their deepe hatred to Mankynd, and the
wonderfull workes of God in their Creation, and Destruction.

Necessary and profitable to all sortes of Men: Collected out of diuine Scriptures, Fathers, Phylosophers, Physitians, and Poets: amplified with sundry accidentall Hystories, Hieroglyphicks, Epigrams, Emblemes, and Enigmaticall obseruations. By EDVVARD TOPSELL.

The Beas

LONDON,
Printed by William Iaggard, 1608.

FIG. 1. TITLE PAGE OF EDW. TOPSELL'S "HISTORIE OF SERPENTS"

readers the works of the early naturalists, interest in the fearsome creatures reported from strange lands beyond the sea and little known oceans became widespread. This is not surprising. Many of these early works were embellished with illustrations which could not fail to catch the eye and enchain the interest, even of the most casual. And then the text! Even today, who can read, for example, these words from the famous "Voyages and Travels of Sir John Mandeville" without a thrill of wonder, so convincing is the exuberance and certainty of the glowing phraseology! The passage I quote is from that portion of the "Travels" in which the author is describing the inhabitants of various islands, or "yles", as he calls them, in some far southern ocean;

> And in another yle are foule men that have the lippes about the mouth so greate, that when they sleepe in the sonne they cover theyr face with the lippe. And in another yle are lytte men, as dwarfes, and have no mouth, but a lyttle rounde hole & through that hole they eate theyr meate with a pipe, & they have no tongue, & they speake not, but they blow & whistle, and so make signes to one another. In Ethiope are such men as have but one foote, and they go so fast yt is a great marvaill, and that is a large foote, that the

shadow thereof covereth ye body from son or rayne, when they lye upon their backes; and when theyr children be first borne they loke like russet and when they waxe olde then they be all black.

It appears that the most credulous times were during the fourteenth, fifteenth and sixteenth centuries. No tales which travelers brought from remote lands or seas, no statements taken out of early writers, were too gross for belief. Quite naturally the less accessible the lands from which the travelers returned, the less frequented the seas over which the adventurous mariners voyaged, the more grotesque and fearful were the monsters reported as having been seen, partially seen,

Thierbuch.
Alberti Magni / Von Art Natur
vnd Eygenschafft der Thierer Als nemlich Von Vier
füssigen Vögeln Fyschen Schlangen oder kriechenden
Thieren / Vnd von den kleinen gewürmen die man
Insecta nennet Durch Walthervm
Ryff verteutscht.
Mit jhren Contrafactur
Figuren.
Begnadet mit Keyserlicher freiheit in Sybē
Jar nit nach zutrucken.

FIG. 2. TITLE PAGE OF ALBERTUS MAGNUS' "THIERBUCH"

or heard of. The natural histories of these days were not, it can be seen, records of careful observations by trained observers. They were a mixture of travelers' tales and compilations of earlier authors. Much of this compiled material was from Pliny, who in his turn had drawn upon Aristotle, and others. The "physiologus" and the various bestiaries also furnished an abundance of animal anecdote, chiefly mythical.

These early books are by no means dull reading, even today. They teem with curious anecdotes concerning all sorts of marvelous creatures,

FIG. 3. THE ERINUS FROM ALBERTUS MAGNUS' "THIERBUCH"

Zedroſus.
Zedroſus iſt ein Meerwunder / der art der Walfiſch / haltet ſich in
Arabiſchem meer / von ſeinen rypen pflegt man in ſolchem Land: / ſtare
bogen vnd gewelb / vnnd andere gebey inn koſtlichen gebewen / vnnd Kō
niglichen Pallaſten zubawen / denn man findet der rippē oder mittel grad
ſes Fiſches / die etwan auff vil ſchu lang ſind.

FIG. 4. THE ZEDROSUS, FROM ALBERTUS MAGNUS' "THIERBUCH"

OF THE VNICORNE.
E are now come to the hiſtory of a beaſt, whereof diuers people in
euery age of the worlde haue made great queſtion, because of the
rare Vertues thereof; therefore it behoueth vs to vſe ſome dilli-

FIG. 5. THE UNICORN, FROM EDW. TOPSELL'S "HISTORIE OF FOUR-FOOTED BEASTES"

creatures who are described either as of positive benefit to man or as of positive evil. Note for example the naive way in which Topsell, in the title page of his "Historie of Serpents" (Fig. 1) describes them as bearing "deepe hatred to Mankind." The title page referred to also gives us a hint of the manner of compiling these early natural histories, for Topsell tells us that his accounts are, "Collected out of diuine Scriptures, Fathers, Phylosophers, physitians, and Poets: amplified with sundry accidentall Histories, Heirogliphicks, Epigrams, Emblems, and Aenigmaticall obseruations." Who can doubt that a book heralded by so enticing a title page would engross the interest of even the most casual general reader? And the frontispiece! Could anyone pass over it in apathy? Would not the terrible Boas here shown be the ogre of childhood, the fear of the traveler, the subject of countless discussions and yarns among all sorts and conditions of men? In comparison with some of the marvelous "beastes" of primitive zoology how insipid and uninteresting are our "real" creatures of today. How can even a ninety-foot sperm whale, blowing his column of pearly spray high in the air, compete successfully in interest with a fire-breathing dragon, whose scales were of gold, and who withered and blasted by his very glance?

The illustrations in this article were photographed from several of the most important of the early works on natural history, books which are now extremely rare and to be found only in college libraries or in extensive collections. They represent creatures, which, in the opinion

of the writer, touch the pinnacle of the absurd in imaginative zoological conception. With the exception of the unicorn and the basilisk, they are practically unknown except to students of the history of zoological thought.

It must not be supposed that the only interest attaching to these curious creatures of bygone days is in the amusement they afford. To the historian of zoology they are significant as indicative of various epochs in the development of biological conceptions.

With the unicorn and the sea-serpent (Fig. 7) we are already somewhat familiar. In Fig. 5 is shown Topsell's superb illustration of the former, and surely no unicorn figured in any of the other early writers, rejoiced in the possession of a more impressive horn? In this figure is also shown a portion of the quaint old text. Topsell's phraseology is most rich quaint, and yet graceful. Listen, as he discourses "of the Unicorne' " . . . by the Unicorne wee doe understand a peculiar beaste, which hath naturally but one horne, and that a very rich one that groweth out of the middle of the foreheade. . . . Likewise the Buls of *Aonia* are saide to have hooves and one horne growing out of the middle of their foreheads. . . . Now our discourse of the Unicorne is of none of these beasts for their is not any vertue attributed to their hornes." He tells us that there is a "vertue" in the horn of the unicorn, but that there are many who cannot believe that this is so. Of this "vertue," he say, "ther were more proofes in the world, because of the noblenesse of his horn. . . . they have ever been in doubt: by which distraction it appeareth unto me that there is some secret enemy in the inward degenerate nature of man, which continually blindeth the eies of God his people from beholding and beleeving the greatnesse of God his workes."

The Gorgon (Fig. 6) is another of Topsell's famous illustrations, to be found on the title page of his "Historie of the Four Footed Beastes".

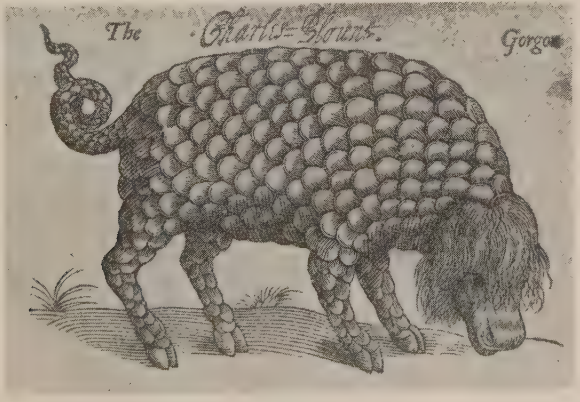


FIG. 6. THE GORGON, FROM THE TITLE PAGE OF EDW. TOPSELL'S "HISTORIE OF FOUR-FOOTED BEASTES"

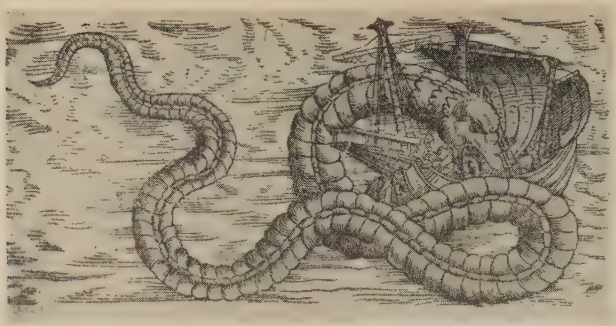


FIG. 7. THE SEA SERPENT, FROM KONRAD GESNER'S "HISTORIAE ANIMALIUM," COPIED FROM OLAUS MAGNUS

Topsell's chief interest was in the larger forms of animal life, as his work, in two parts, attests.

In Ulysses Aldrovandus, however, we find a naturalist to whom the lowlier forms of life made more appeal. His tremendous folio volume on insects and other primitive creatures, published in Latin in 1602, contains many curious forms not known to zoologists of the present day. Fig. 8 is one of these bizarre forms, a snail, whose remarkable fore limbs are of no less anatomical interest than they are of artistic conception. It is a curious and noteworthy thing how often the early naturalists depicted their beasts with these rather pleasing, leaf-like appendages, slashed into fringes and lobes. No doubt they thought that this gave an artistic "finish" to the beasts, as it indisputably does. In this connection compare the appendages of the creatures in Fig. 9 with Erinus (Fig. 3) and Zedrosus (Fig. 4).

The sea-serpent has been with us from time immemorial and in some sections of the country belief in it still lingers with tenacious hold. Fig. 7, taken from Konrad Gesner's "Historiae animalium" shows a mediaeval conception of this terror of the sea, a conception which certainly depicts the serpent in all his fabulous terrors. Note the ease with which he arches his back and selects out the fattest seaman of

FIG. 8. A UNIQUE SNAIL, COCHLEA, FROM ALDROVANDUS' "DE ANIMALIBUS"

FIG. 9. A GROUP OF SEA MARVELS OR "MEERWUNDERN," FROM ALBERTUS MAGNUS' "THIERBUCH"

the crew of the helpless vessel. Of illustrations of sea-serpents there are legion. This one I have selected as fulfilling perhaps our most morbid notions of a creature, than whom nothing more awful exists in the sea of our imagination.

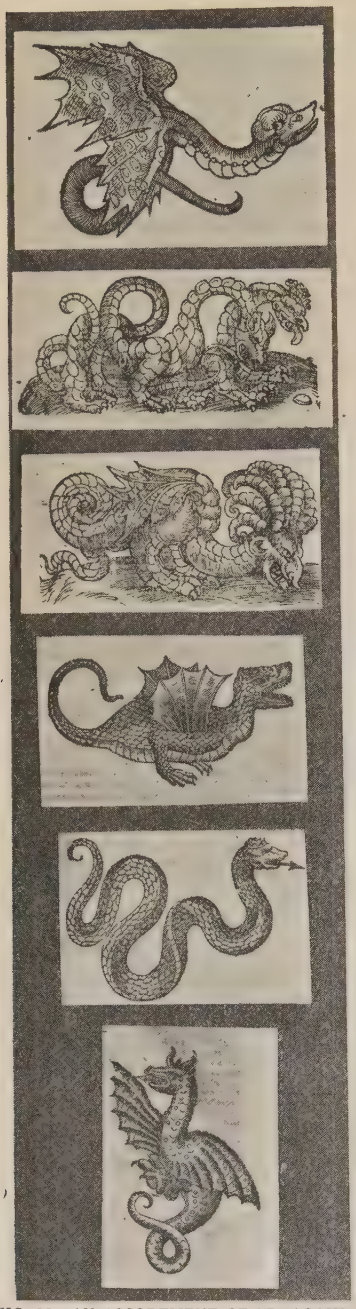


FIG. 10. AN ASSORTMENT OF "DRAGONS AND CHIMAERAS DIRE," FROM ALBERTUS MAGNUS, TOPSELL, ALDROVANDUS AND GESNER

Dragons, chimaeras, basilisks, cockatrices, and gorgons, seemed to have exerted a by no means meagre fascination for the early writers. Accounts of them are numerous and lengthy in almost all of the old works. Nor were their habits less strange than their forms. Of fierce and vindictive dispositions, in league often with the Evil One himself, breathing fire, and blasting or killing by their very glance or touch, they formed a theme upon which the credulous old naturalists were never tired of descanting. In Fig. 10 is shown a group of typical "dragons and chimaeras dire" from Albertus Magnus, Aldrovandus, Topsell, and Gesner. Topsell in his long discussion of dragons, says of one sort: "Their aspect is very fierce and grimme, and whensoever they move uppon the earth, their eyes give a sound from theyr eyeliddes, much like unto the tinckling of Brasse. . . ." And again, speaking of the classification of dragons he says: "There be some dragons which have wings, and no feete, some again have both feete and wings, and some neither feete nor wings, but are onely distinguished from the common sort of Serpents by the combe growing uppon their heads and the beard under their cheekes."

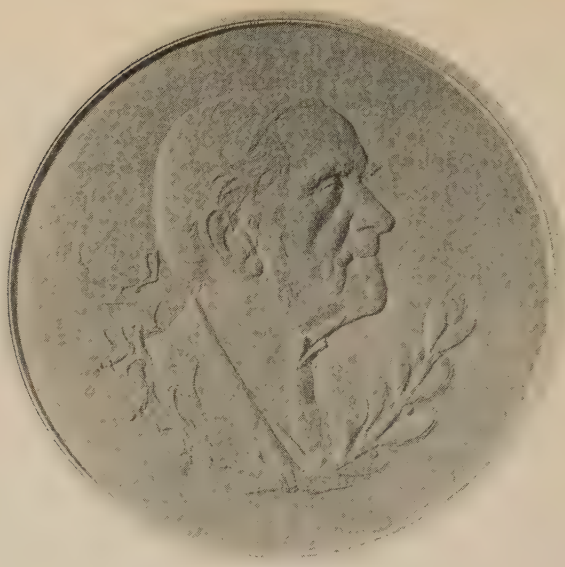
Those, however, who wish to be ushered into a world more populous in bizarre and marvelous animal forms than any other of which the writer is aware, have but to open the magic door of Albertus

Magnus' immortal "Thierbuch," unfortunately for those who read no language but English, written in rather antiquated German. A copy of this rare work (printed in 1545), in heavy embossed leather with brass clasps, and riddled with bookworm holes, fell into the author's hands recently. From it were photographed the title page (Fig. 2) and the "Meerwundern", or sea marvels (Fig. 9), Albertus Magnus begins his pretentious work with the story of Adam and Eve (so as to be certain that he makes a start from the very beginning) and then follows this with accounts of all sorts of creatures; accounts illustrated with figures beautifully drawn, and embellished, in many cases, with artistic flourishes of the artist's own. In the figure of the Zedrosus (Fig. 4) is included some of the text, a beautiful example of the artistic typography of the times. The letters are clear, bold, and easily read, and the style of the font of type pleasing in its proportions. In Fig. 9 is shown a group of sea marvels, or "Meerwundern", a title which no one would presume to dispute. In the writer's opinion, however the Ultima Thule of absurdity is attained in the conception of the beast Erinus (Fig. 3). Albertus (no wonder he was accorded the title of "the great") says of this creature: "Erinus is also a fish in the water which has its mouth and face bent down under itself, and the opening for the excreta located above." He tells us that, according to Pliny it is feared by other fishes, and that its flesh is red, like cinnabar. Truly a fearful "Wunder" was the Erinus.

It might appear that the author is in sympathy with the early writers only when they happen to afford amusement. This is far from being the case. No one can read the early writers without a smile, it is true; nevertheless he is a blind reader indeed who cannot detect the true purpose of these sturdy though credulous old naturalists, who cannot perceive that their one ambition was to further the bounds of natural knowledge, to glorify the Creator by showing forth the wonders of His works, and lastly, and in this case also least, to acquire some renown for themselves.

In conclusion listen to these words of Topsell, in his Epilogue to the "Historie of Four Footed Beastes":

> If you think my endeavors and the Printers costs necessarie and commendable, and if you woud ever farther or second a good enterprise, I do require al men of conscience that shall ever read, hear, or see these Histories or wish for the sight of the residue, to helpe us with knowledge, and to certifie their particular experiences of any kinde, or any one of the living Beastes: and withall to consider how great a task we do undertake, travelling for the content and benefit of other men, and therefor how acceptable it would be unto us, and procure everlasting memorie to themselves to be helpers, incouragers, ayders, procurers, maintainers, and abbettours, to such a labor and needfull endeavor, as was never before enterprized in England.



MEDAL IN HONOR OF DR. STEPHEN SMITH

The plaque (photographed by Paul Thompson) from which the souvenir medal in honor of Dr. Smith was made. It was modeled by Michele Martino, the New York sculptor.

THE PROGRESS OF SCIENCE[1]

THE AMERICAN PUBLIC HEALTH ASSOCIATION

New York has been the scene of semi-centennial meetings of the American Public Health Association from November 8 to 19. During the first week, there was a public health institute which included demonstrations on vital statistics, hygiene of mother and child, public health nursing, socio-health, sanitary engineering, communicable diseases, laboratory work, food and drugs and industrial hygiene. This was the occasion for visits to clinics, stations, institutions, centers, laboratories, hospitals, water and sewage plants, and other public health activity centers in New York City and its vicinity.

During the week of November 14, the largest health exposition ever attempted was held at the Grand Central Palace through the cooperation of the American Public Health Association and the Department of Health of the City of New York. This exhibit was marked by many novelties, such as children's health games, fat reducing squads, perfect baby contests, perfect teeth and foot contests. Social service and scientific organizations joined in the exhibition. Among them were the National Tuberculosis Association, the National Health Council, the American Social Hygiene Association, the American Museum of Natural History, the American Society for the Control of Cancer and the National Committee for Mental Hygiene.

The fiftieth annual meeting of the association, held from November 14 to 18, included both general and scientific sessions. Representatives from Canada, Cuba and Mexico, as well as all parts of the United States, were in attendance. Dr. Mazyck P. Ravenel, as president of the association, delivered the principal opening ad-

[1] Edited by Watson Davis, Science Service.

DR. STEPHEN SMITH

Founder of the American Public Health Association, which is now celebrating its fiftieth anniversary. Although 99 years of age, Dr. Smith is active in the work of the association.

dress. The scientific papers and addresses included a wide variety of subjects under the general topics of public health administration, laboratory work, vital statistics, food and drugs, sanitary engineering, industrial hygiene, child hygiene, health education and publicity. In commemoration of the semi-centennial celebration, the association is also publishing a jubilee historical volume.

Attending these sessions, and guest at a banquet in his honor, was Dr. Stephen Smith, who fifty years ago founded the American Public Health Association and became its first president. Though now ninety-nine years old, Dr. Smith still takes an active part in the affairs of the association. He was further honored during the health fortnight by a souvenir bronze medal bearing his portrait and fittingly inscribed to denote his participation in the fiftieth annual meeting. In addition to his activities in the American Public Health Association, Dr. Smith has been a leader in city and national health work. He is the author of books on surgery and other medical subjects and before the Civil War was editor of several medical journals. As surgeon, he has served Bellevue Hospital many years, and in 1896 he represented this country at the Ninth International Sanitary Convention.

SCIENTIFIC PROBLEMS OF THE PACIFIC

The Pacific Division of the American Association for the Advancement of Science at its recent meeting in Berkeley endorsed the idea of the Washington Conference on the Limitation of Armaments and Pacific Problems and offered the services of scientific men to the President of the United States for solving such Pacific problems as may require expert scientific knowledge.

Dr. William E. Ritter, director of the Scripps Institution for Biological Research, La Jolla, California, writes:

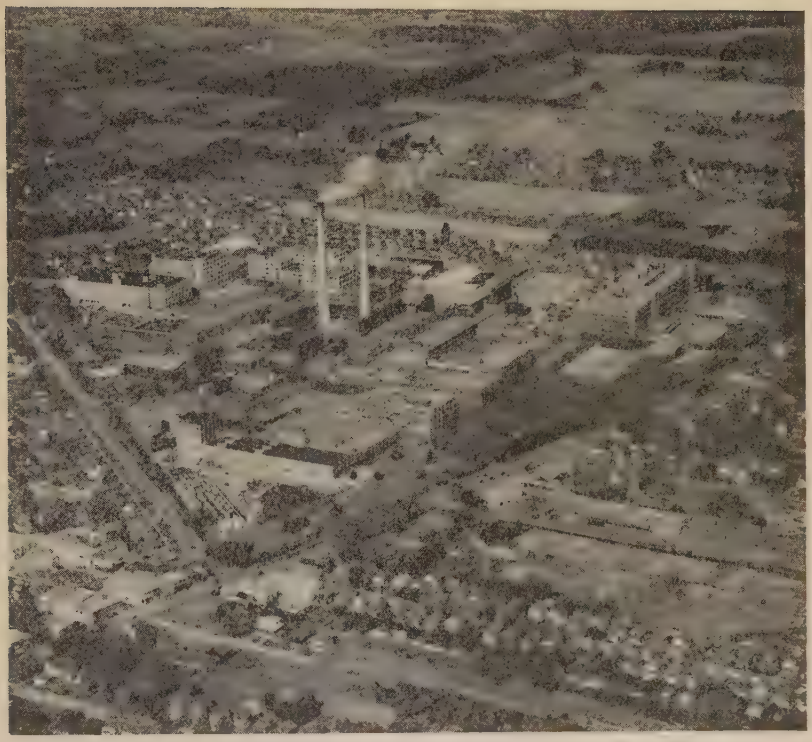
The resolutions adopted had two aims. One was generally informative. It would let the government and people of the United States know, so far as it might, where the scientists thus expressing themselves stand relative to the purposes of the conference. The hope was that the resolutions would do something toward correcting the belief, now too prevalent, that science is in effect more favorable than unfavorable to the militaristic type of international dealing. The other aim was more concrete. It would make scientific knowledge and research, and technical skill, positive factors in solving international problems by intelligence, which usually follows the way of peace, instead of by emotion, which usually follows the way of war.

The National Research Council has a committee on Pacific Investigations composed of: Herbert E. Gregory, chairman, Bishop Museum, Honolulu, Hawaii; T. Wayland Vaughan, vice-chairman, United States Geological Survey; William Bowie, United States Coast and Geodetic Survey; Barton W. Evermann, California Academy of Sciences; John C. Merriam, Carnegie Institution of Washington; William E. Ritter, Scripps Institution for Biological Research; W. T. Swingle, United States Department of Agriculture; and Clark Wissler, American Museum of Natural History.

GOVERNMENT EDUCATIONAL COURSES

Two scientific branches of the government are helping their scientific staffs to become more useful to themselves and to the government by offering the opportunity to take courses of graduate study after office hours.

For more than ten years the Bureau of Standards has been maintaining advanced courses in physics, mathematics and chemistry, and this year the Department of Agriculture has inaugurated a system of advanced instruction in those scientific and technical subjects related to the work of the department in which adequate instruction is not available in Washington.



AN AIRPLANE VIEW OF KODAK PARK, THE PLANT OF THE EASTMAN KODAK COMPANY

It is expected that the successful completion of any of the courses will be recognized for adequate credit in some of our better educational institutions, both for undergraduate and for postgraduate work. This has already been the case with the Bureau of Standards courses.

Those offered this year at the Bureau of Standards include: Advanced optics by Dr. C. A. Skinner; differential equations by Dr. L. B. Tuckerman; chemical thermodynamics by Dr. L. H. Adams of the geophysical laboratory; interpretation of data, including the theory of errors and methods for numerical, graphical and mechanical computation, by Dr. Chester Snow.

The courses of study at the Department of Agriculture were worked out by a committee from the various bureaus of the department headed by Dr. E. D. Ball, formerly assistant secretary and now director of the scientific work of the department.

There are two more or less distinct kinds of work offered: (a) lecture and drill courses on certain fundamental subjects in which the personnel of two or more bureaus may be interested; (b) intensive graduate training in special topics.

The courses now being given at the Department of Agriculture are: Agricultural Economics, by Dr. H. C. Taylor; Statistical Methods, by H. R. Tolley; Biochemistry, by Dr. C. O. Appleman; Mycology, by Dr. C. L. Shear; Plant Physiology, by Dr. Burton E. Livingston; Genetics, by Dr. Sewall Wright; Physics of the Air, by Dr. W. J. Humphreys; Statistical Mechanics applied to Chemical Problems, by Dr. R. C. Tolman.

THE OPTICAL SOCIETY OF AMERICA

At the sixth meeting of the Optical Society of America, held in Rochester, N. Y., the most notable feature was the Helmholtz Memorial Meet-

ing held on the afternoon and evening of October 24. The afternoon program was as follows:

A brief survey of the historical development of optical science: PROFESSOR J. P. C. SOUTHALL.

Helmholtz's early work in physics—the conservation of energy: PROFESSOR HENRY CREW.

Helmholtz's contributions to physiological optics: L. T. TROLAND.

Professor Crew exhibited lantern slides showing Helmholtz at the time he wrote the essay on the Conservation of Energy (age 26) and also at later periods of his life.

At the evening session, Professor M. I. Pupin spoke informally and in a most interesting and delightful manner on his Personal Recollections of Helmholtz. Professor E. L. Nichols, Professor Ernest Merritt, Dr. Ludwik Silberstein, Mrs. Christine Ladd-Franklin and Professor C. R. Mann also spoke of their memories of Helmholtz as a teacher. Professor Mann showed a lantern slide of a photograph which he himself made on July 7, 1894, showing Helmholtz at his lecture desk only a few days before his last illness.

At the regular sessions of the society some twenty papers were presented, special attention being given to physiological optics. A committee was appointed, the duty of which is: (1) To prepare the program of the sessions on vision; (2) to coordinate the work of the society in this field with the work of other societies and (3) to recommend, from time to time, such further steps as may be deemed effective in encouraging research in physiological optics and allied problems.

Rochester is the world's chief center for the manufacture of optical and photographic apparatus. Visits were arranged to go through the research laboratories of the Eastman Kodak Company and the glass plant, optical shops and observatory of the Bausch and Lomb Optical Company. The research work of these laboratories is of great magnitude and even in contributions to pure science may soon rival the chemical and physical laboratories of any university.

SCIENTIFIC ITEMS

WE record with regret the death of Alexander M. Gray, professor of electrical engineering in Cornell University; of Seymour C. Loomis, formerly secretary of the section of social and economic sciences of the American Association for the Advancement of Science; of Dr. Emil A. Budde, German electrical engineer; of Emile Houzé, professor of anthropology at the University of Brussels and at the Ecole d'Anthropologie of that city; and of Sir William Edward Garforth, pioneer worker for safety in coal mines.

DR. HARLOW SHAPLEY, formerly of the Mount Wilson Solar Observatory, has been appointed director of the Harvard College Observatory in succession to the late Edward C. Pickering.

PROFESSOR GEORGE C. COMSTOCK, who has been director of the Washburn Observatory at the University of Wisconsin since 1889, will retire at the end of this year. His place will be taken by Dr. Joel Stebbins, formerly of the University of Illinois department of astronomy and director of its observatory since 1913.

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